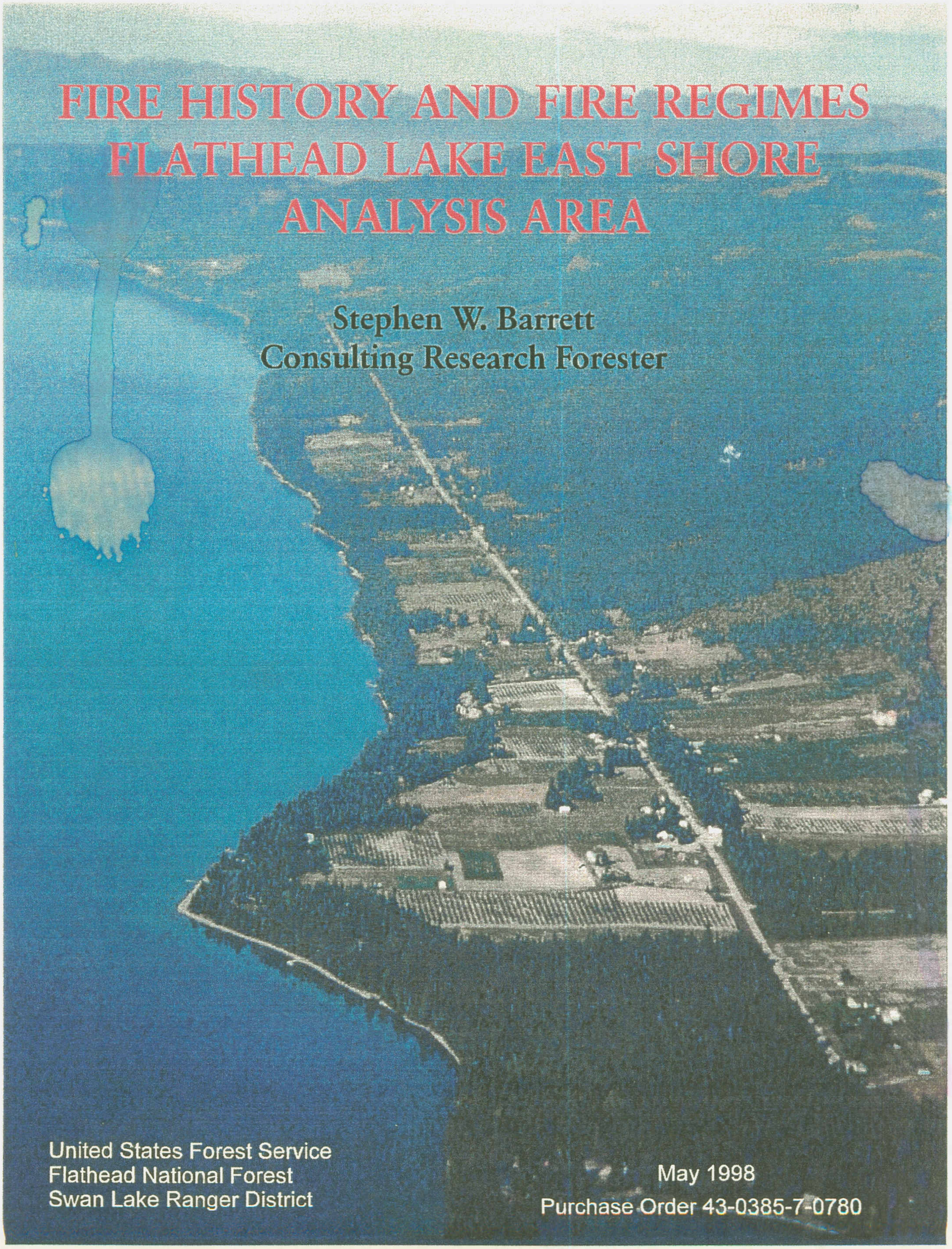
FIRE HISTORY AND FIRE REGIMES FLATHEAD LAKE EAST SHORE ANALYSIS AREA

Stephen W. Barrett
Consulting Research Forester



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CONTENTS

INTRODUCTION

During the summer of 1997, a fire history assessment was conducted for the East Shore Analysis Area on the Flathead National Forest (FNF), northwestern Montana (fig. 1). The goal was to determine area fire history and fire regimes to help managers design possible strategies for ecosystem management. Specific objectives were to: 1) sample presettlement fire history, 2) model presettlement fire regimes, and 3) document the effects of attempted fire exclusion after 1900.

The study area encompasses about 6000 acres of montane forest on lower Crane Mountain (2900-5000 ft. elev.), adjacent to the east shore of Flathead Lake. Relatively dry stands are dominated by various mixes of ponderosa pine, western larch, and Douglas-fir (i.e., warm-dry habitat types in the Douglas-fir- and grand fir series [Pfister et al. 1977]). Conversely, moist sites support diverse combinations of western larch, lodgepole pine, and Douglas-fir (i.e., primarily warm-moist and cool-moist grand fir and subalpine fir habitat types).

METHODS

The methods of Arno and Sneck (1977) and Barrett and Arno (1988) were used to sample fire history. Specifically, partial cross-sections were sawn from fire scarred trees, and an increment borer was used to sample fire-regenerated age classes along transects coursed through the study area. At each sample site, forest cover type and habitat type were documented in 375 m^2 circular plots. Successional trends were documented in the plots by estimating the canopy coverages of each tree species by four d.b.h. classes: 1) seedlings/saplings [0-4 in.], 2) poles [4-12 in.], 3) mature trees [12-30 in.], and 4) old growth trees [30+ in.].

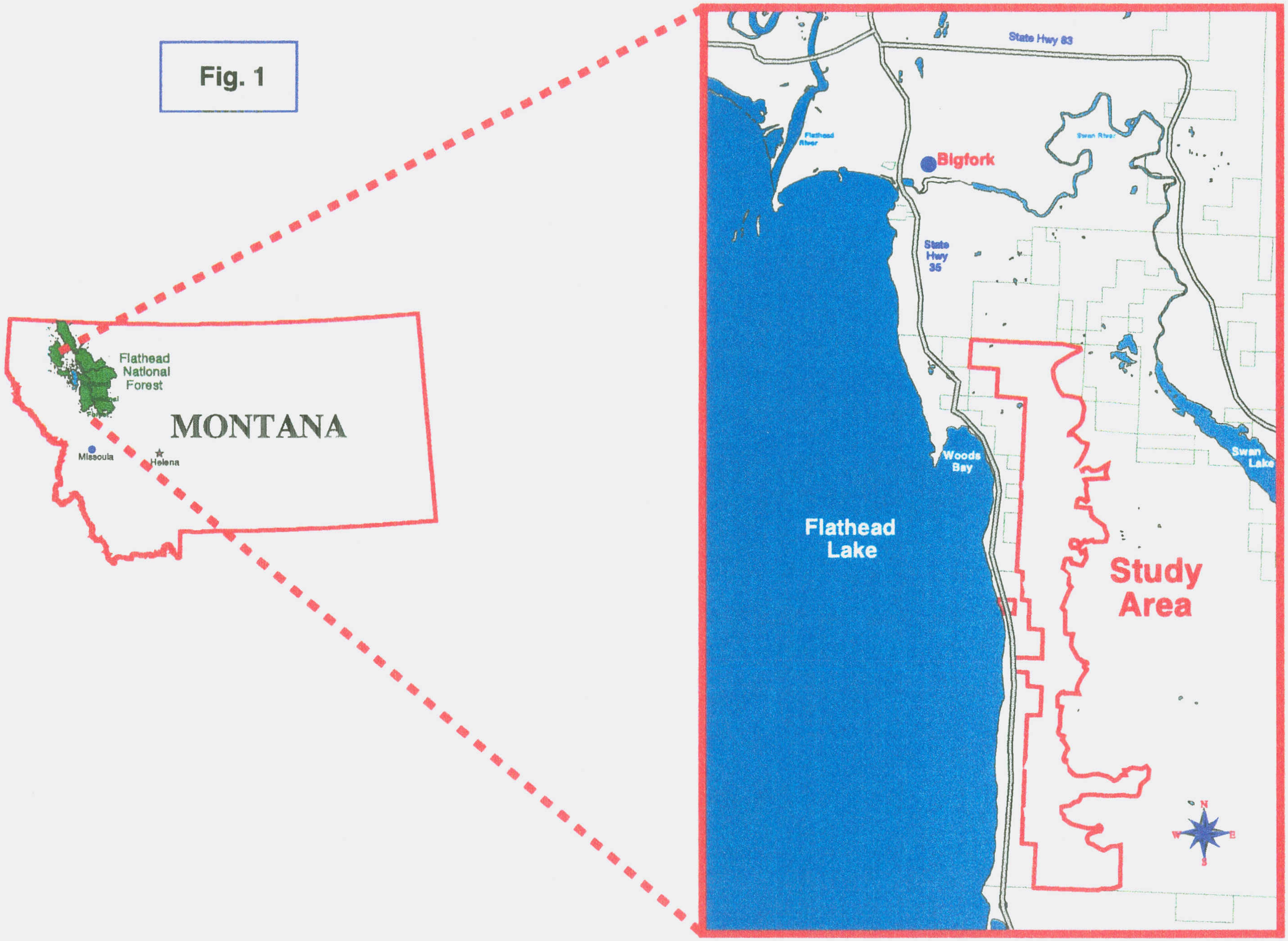
The fire scar- and increment core samples were air-dried and sanded, then analyzed with a 10-20x binocular microscope. Fire year estimates were compiled into stand- and study area master fire chronologies (Romme 1980, Arno and Peterson 1983), as follows. Closely similar scar year estimates were adjusted to those obtained from nearby samples yielding the clearest ring counts. Then stand fire chronologies were produced by listing the estimated fire years and fire intervals for each site (Arno and Peterson 1983). Stand structure was determined by examining the piths of sample trees relative to the stand fire years, to assess whether the stands were even- or uneven aged. Subsequently, the fire year data were organized into a master fire chronology (Romme 1980) for the entire study area, enabling an analysis of coarse-scale fire frequency.

Fire frequency was analyzed for each sample stand, and for the entire study area, as follows. The fire year data were used to calculate: 1) mean fire interval [MFI], 2) fire interval range, and 3) number of years since the last fire. For planning purposes, the first two pieces of data above document the natural range of variability in presettlement fire frequency, for both the stand- and landscape scales. Conversely, the effectiveness of attempted fire exclusion is measured by the years-since-last-fire data.

RESULTS AND DISCUSSION

Sampling at 50 sites produced 136 fire scar cross sections and increment cores from fire-regenerated seral age classes. The earliest fire evidence dated from about 1460 A.D., a remnant fire-scarred larch in the mid-Parker Creek drainage (i.e., plot 41). However, the relatively continuous portion of the tree ring record spans from circa 1513 to 1920. The 1920 burn was the last fire of any

Fig. 1


Flathead
National
Forest
MONTANA
Missoula
Helena
State Hwy 83
Flathead
River
Swan River
Bigfork
State
Hwy
35
Woods
Bay
Flathead
Lake
Swan
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Study
Area
N
E
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W

consequence in the study area, as verified by the sampling and fire atlas (on file, FNF).

The study area master fire chronology (Appendix) contains an estimated 49 fires between 1513 and 1920, yielding an area MFI of about nine years (fig. 2). That is, a fire occurred somewhere in the 6000-acre study area an average of once per decade during the 407 years between 1513 and 1920. Estimated intervals between the fires ranged from one to 32 years. These estimates are undoubtedly conservative because sampling likely will not detect every small fire in a large study area, and tree ring records diminish over time (Arno 1976, Barrett and Arno 1982). For instance, the post-1600 portion of the chronology contains one or more fires in every calender decade until 1920, and area MFI was just seven years. Today's 77-year long fire interval is thus at least nine times longer than the presettlement MFI — strong evidence of effective fire exclusion.

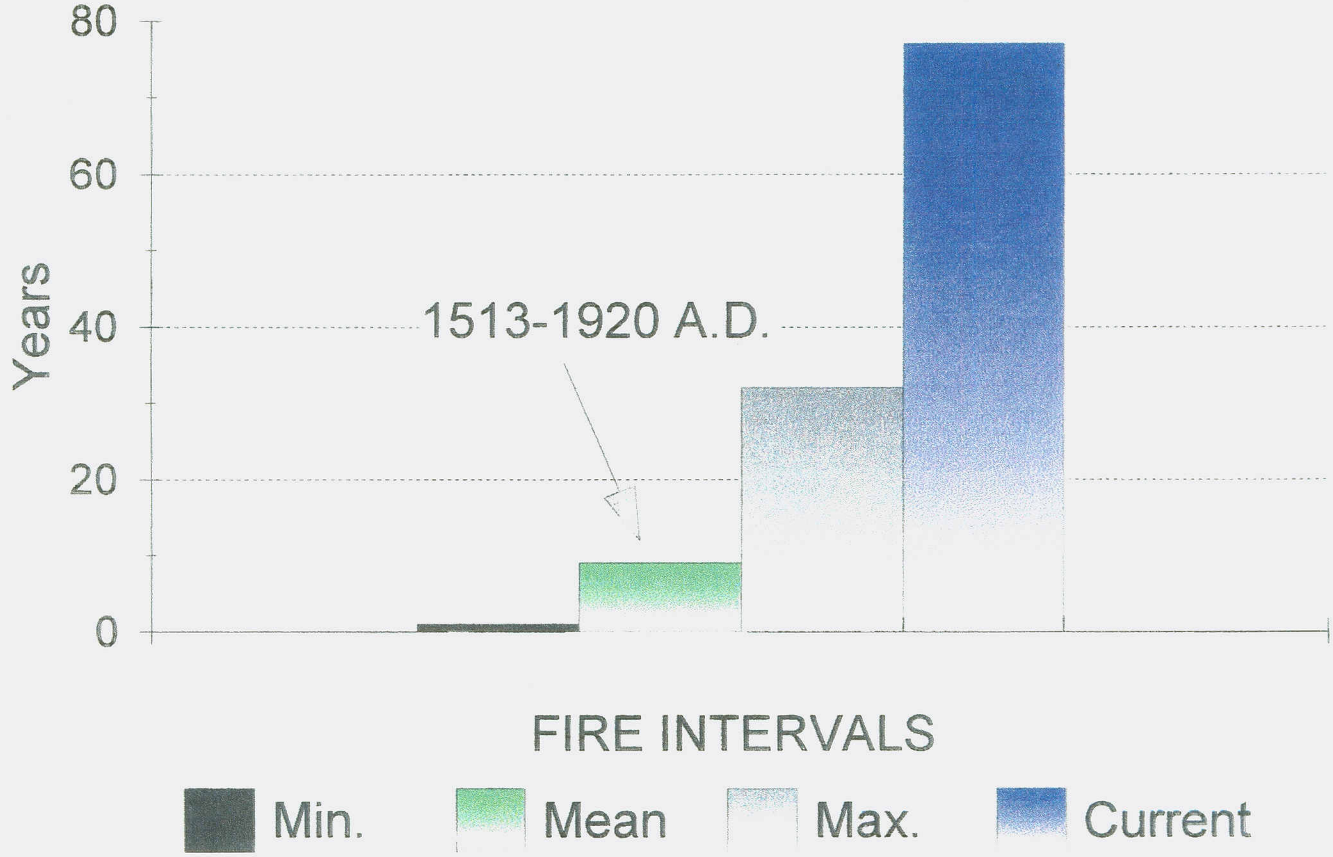
The uniform fire frequency through dry- and wet climatic periods (Karl and Koscielny 1982, Graumlich 1987, Meko et al. 1993, Barrett et al. 1997) suggests that fires may have been caused by lightning and Indians (Barrett and Arno 1982, Gruell 1985). And fire atlas records show that Crane Mountain still experiences high fire frequency when compared with other areas of the Flathead National Forest. Since 1974, for example, lightning and humans have caused nearly 100 fires in and next to the study area (fig. 3), averaging four ignitions per year. Lightning fires have also been unusually uniformly distributed on Crane Mountain, further enhancing fire potential. However, most fires in this century have been quickly suppressed at less than one-quarter acre in size. In contrast, the presettlement fire frequency suggests that as many as 15 spreading fires might have occurred since 1920.

High presettlement fire frequency and advancing forest succession over the last eight decades have largely obscured old burn margins. Based on the plot locations, most fires apparently were limited in extent. Ninety-six percent of the fires in the chronology were recorded in five or fewer (<10%) of the sample plots, which were well distributed throughout the study area. Moderate- to large size fires occurred five or six times between about 1650 and 1920 (fig. 4), which is the most complete portion of the chronology. Such fires, recorded in at least 25 percent of the plots, averaged about every 50 to 70 years. The two largest fires, in 1805 and 1893, were represented in 48 percent and 44 percent of the plots, respectively. These fires may have burned between 50 and 75 percent of the study area. However, the widespread fire scarred trees show that even these fires did not burn in a stand replacement pattern. Also note that the term "major fire" relates only to the 6000-acre study area, which is smaller than many wildfires. The study area has not experienced a major fire in 104 years — versus 88 years between the 1805 and 1893 events.

Stand Fire Patterns. Fire scarred trees ranged from scarce to common in a given stand, and most stands contain multiple fire-regenerated age classes. Such evidence suggests an overall pattern of mixed severity burning, rather than stand replacement- or nonlethal fires (Barrett et al. 1991, Agee 1993, Quigley et al. 1996). In fact, a 1902 photograph of Daphnia Pond, about one mile northwest of the study area, shows snags and groups of surviving trees after a recent mixed severity fire (Gruell 1983).

The sampling revealed two distinct mixed severity fire regimes in the study area. That is, different fire frequency- and severity patterns were found in dry- versus moist forest cover types.

Fig. 2. Study Area Fire Frequency
Flathead Lake East Shore



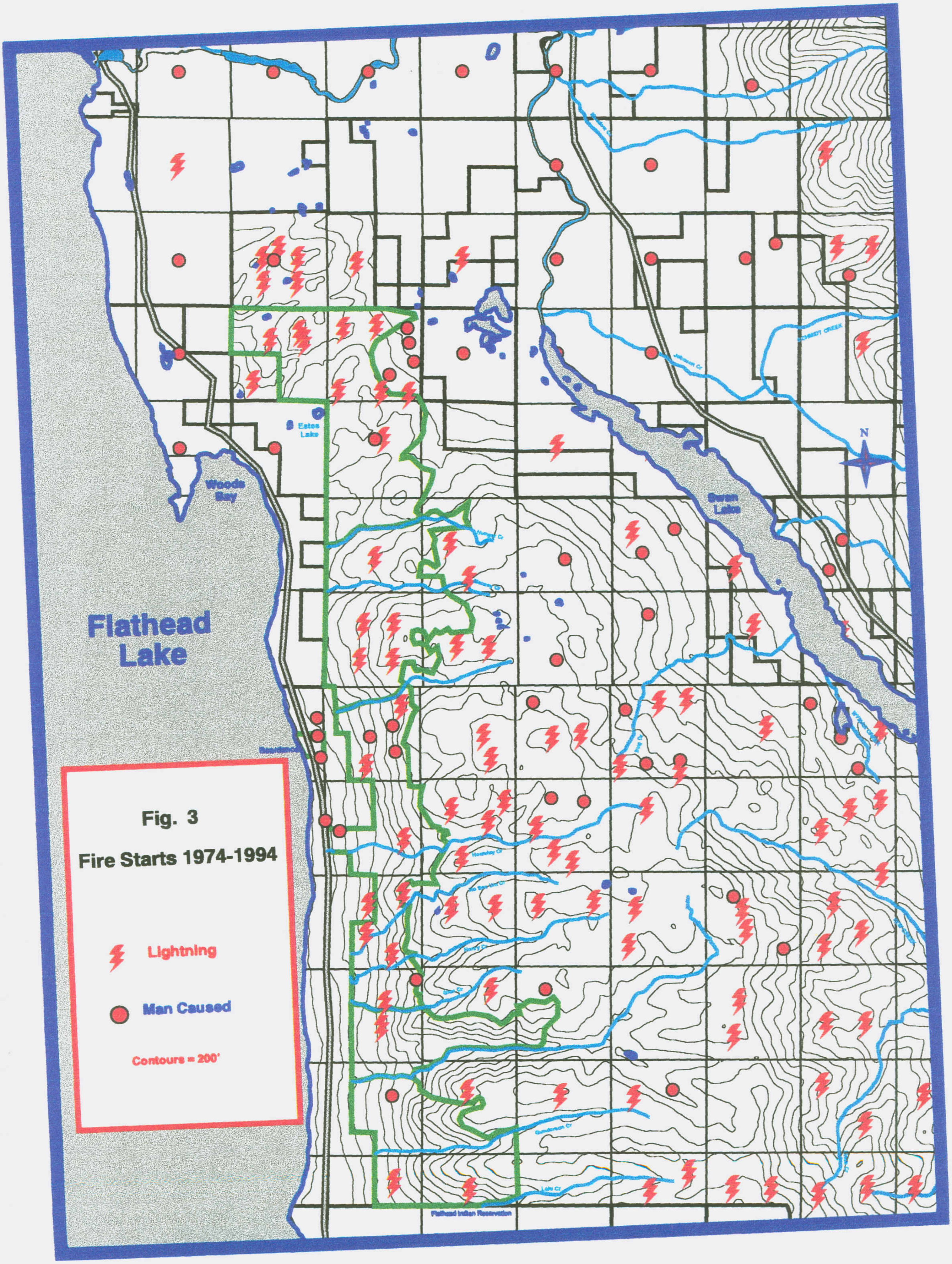
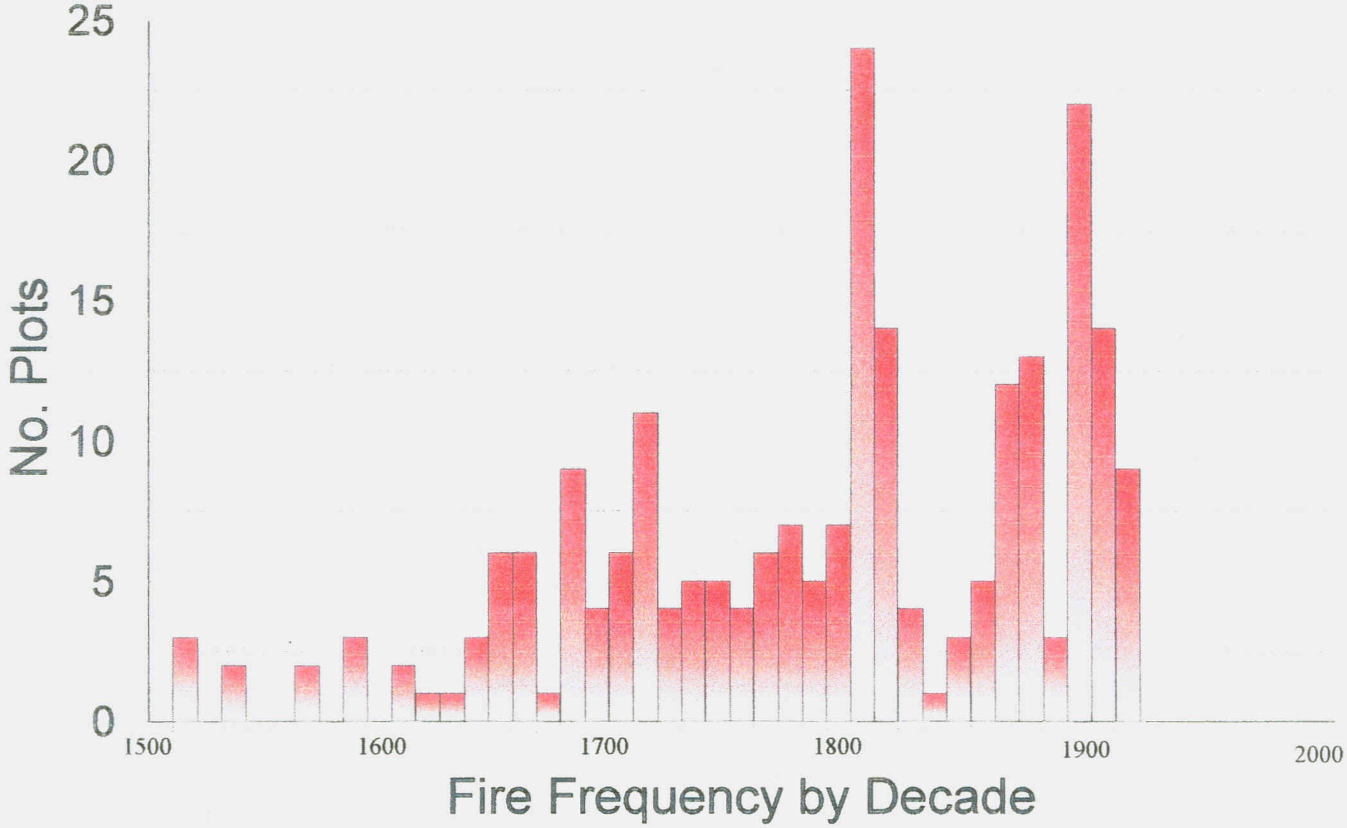


Fig. 3
Fire Starts 1974-1994

Fig. 4. Master Fire Chronology
1513-1997 A. D.



Ponderosa Pine Cover Types. Long-term data were obtained from 15 ponderosa pine-dominated stands, and evidence of two fire regimes was found. That is, nonlethal fires frequently occurred on dry, sparsely forested south slopes (e.g., *Psme/Agsp*, and *Psme/Syal* h.t.s). Otherwise, sites dominated by ponderosa pine, western larch, and Douglas-fir (e.g., *Psme/Phma-Caru* and *Psme/Phma-Phma* h.t.s) experienced mixed severity fires at somewhat longer intervals.

Data documenting the nonlethal regime were obtained from three stands in the study area's minor ponderosa pine-Douglas-fir cover type (table 1, figs. 5-6). Such sites support widely scattered, uneven age ponderosa pine (e.g., *Psme/Phma-Caru* in the "900" series of habitat types). Presettlement MFIs ranged from 16 to 26 years long, and the overall MFI was 21 years long (i.e., 3-stand mean). Average minimum and maximum fire intervals were 8- and 47 years long, respectively. However, the current fire interval averages 98 years long, a fivefold increase over the average presettlement MFI. (Also note that sampling on such sites often yields conservative estimates of fire frequency, because light surface fires often fail to scar trees [Arno 1976, Barrett and Arno 1982]). The shortest intervals were found in plot 46 near lower Gunderson Creek. Fires averaged every 16 years between 1662 and 1883, but the site has not burned during the last 114 years — which is the strongest evidence of fire exclusion in the study area today. Based on the presettlement patterns, as many as ten fires might have been precluded from any given site in the ponderosa pine-Douglas-fir cover type.

Twelve stands were sampled in the warm-moist ponderosa pine-larch-Douglas-fir cover type (e.g. *Psme/Phma-Phma* h.t.)(table 2, figs. 7-8). Fires were comparatively frequent before 1920, and burned at low- to moderate intensities that produced multiple even-age groups in stands (i.e., seral component). Individual stand MFIs ranged from 23 to 38 years long, and the overall MFI was 30 years long. The average minimum- and maximum fire intervals were 10 and 62 years long, respectively. By contrast, current intervals range from 77 to 121 years long, and the overall mean of 107 years represents a fourfold increase over the average MFI. Based on the presettlement fire patterns, as many as five or six fires apparently have been precluded from any given stand in this cover type. This same pattern of moderately frequent mixed severity fires, followed by effective fire exclusion, has been found elsewhere in the Flathead Basin (Freedman and Habeck 1985, Barrett et al. 1991, Arno et al. 1997).

Larch-lodgepole pine-Douglas-fir Cover Type. Data were obtained from 19 stands in the cool-moist western larch-lodgepole pine-Douglas-fir type (table 3, figs. 9-10). Mixed severity fires were less frequent and more severe in these productive habitat types (e.g., *Abgr/Clun-Clun* and *Abla/Clun-Xete*). However, fire intervals were highly variable. Stand MFIs ranged from 26 to 128 years long, but the overall MFI was 78 years. Minimum- and maximum fire intervals averaged from 51 to 106 years long, respectively. By comparison, current fire intervals range from 77 to 124 years long. The overall mean of 90 years since the last fire is only slightly longer than the average MFI, suggesting that many stands are still within the range of presettlement variability. That is, because presettlement fire intervals were often longer than those produced by the fire exclusion period to date, this cover type has been less affected by fire exclusion.

Remnant old larches rarely had more than two or three scars each, whereas ponderosa pines often had six or more scars per tree. Also attesting to relatively severe fires, most larch-dominated stands have few veterans more than 200 years old, whereas ponderosa pines commonly range from 300 to 500 years old. However, fire severities in larch-dominated stands ranged from creeping

Table 1. Fire frequency- and stand data for 3 sample stands in the ponderosa pine-Douglas-fir cover type (*Nonlethal Fire Regime*).

Plot No. [1]	Hab. Type[2]	Asp.	Elev. (ft)	MFC[3]	No. Fires	Intvl. Range (yr)	MFI[4] (yr)	Last Fire[5] (yr)
46	Psme/Phma-Caru	SW	4140	1662-1883	15	8-51	16	114
47	Psme/Phma-Caru	W	5180	1714-1893	9	9-35	22	104
49	Psme/Phma-Caru	S	3980	1662-1920	11	6-56	26	77
			Range:	**1662-1920**	**9-15**	**6-56**	**16-26**	**77-104**
			Mean:	**-**	**12**	**8-47**	**21**	**98**

1. Locations on study area map (on file, FNF).
2. Habitat type acronymns follow Pfister et al. (1977).
3. Stand Master Fire Chronology.
4. Mean Fire Interval.
5. As of 1997.

Fig. 5. Stand Fire Intervals
Nonlethal Fire Regime (PP-DF)

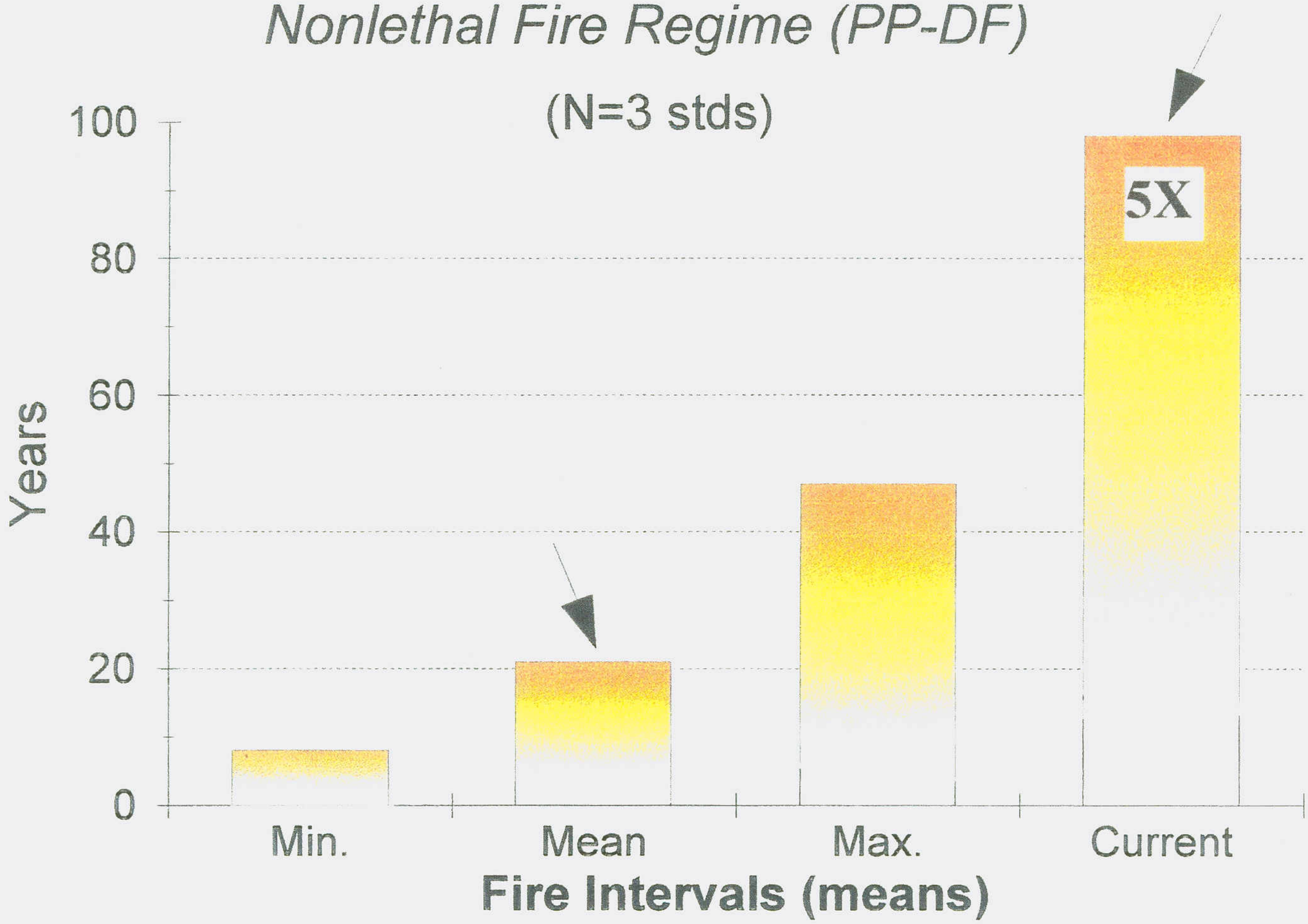


Fig. 6. MFI vs Years Since Last Fire, Nonlethal Regime

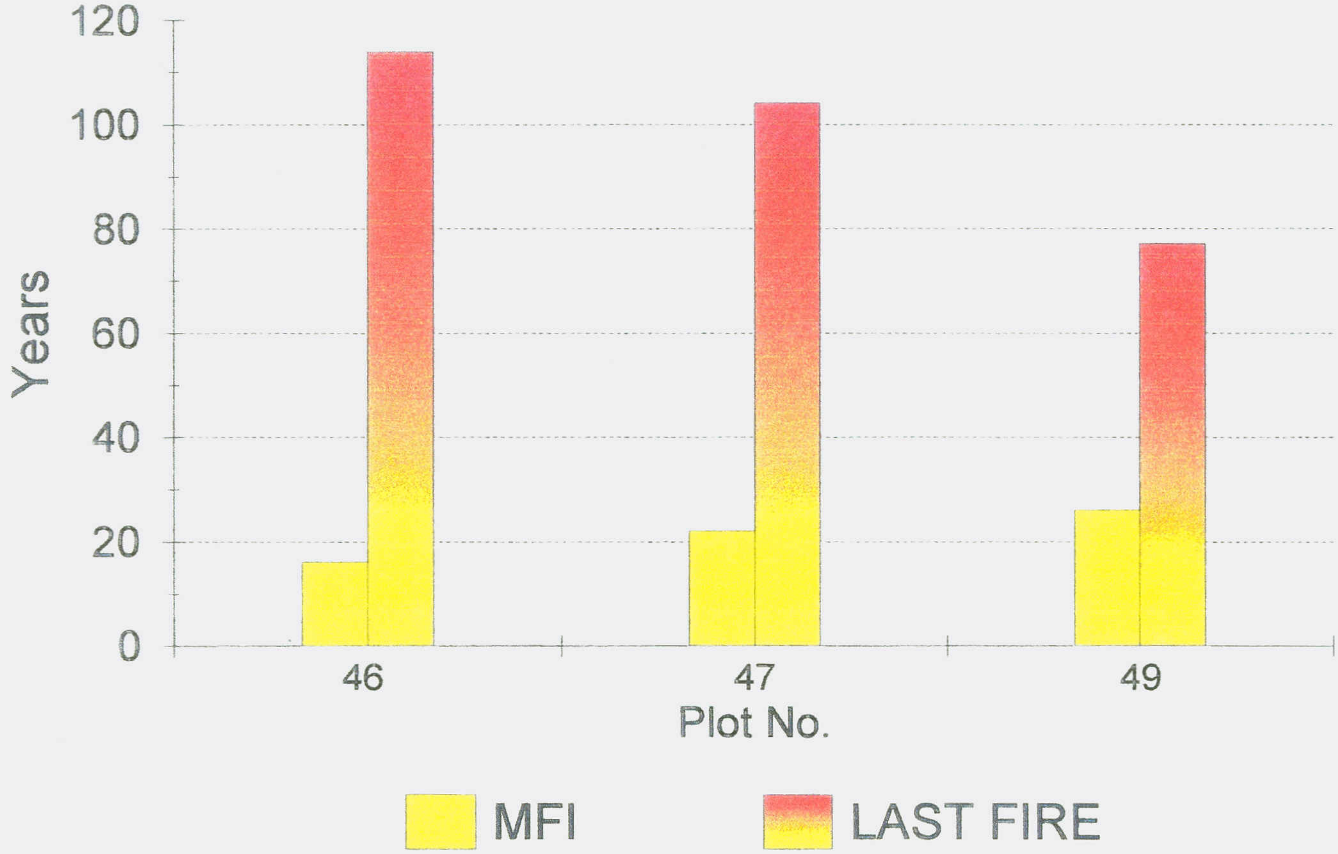


Table 2. Fire frequency- and stand data for 12 sample stands in the ponderosa pine-larch-Douglas-fir cover type (*Mixed Severity I Fire Regime*).

Plot No.	Hab. Type	Asp.	Elev. (ft)	MFC	No. Fires	Intvl. Range (yr)	MFI (yr)	Last Fire (yr)
1/2	Psme/Phma-Phma	W	3160	1627-1920	14	6-63	23	77
4	Psme/Phma-Phma	E	3540	1805-1876	3	9-62	36	121
20	Psme/Phma-Caru	W	4250	1644-1908	12	7-66	24	89
28	Abgr/Libo-Libo	W	4400	1681-1860	6	5-76	36	137
37	Psme/Phma-Phma	SW	4920	1696-1893	7	9-70	33	104
39	Abgr/Libo-Libo	W	4450	1686-1879	7	7-77	32	118
40	Abgr/Libo-Libo	SW	4560	1714-1867	5	15-70	38	130
42	Psme/Phma-Phma	SW	5280	1723-1879	7	9-47	26	118
43	Psme/Phma-Phma	W	3880	1662-1906	11	13-50	24	91
45	Psme/Phma-Caru	W	5200	1805-1889	4	13-55	28	108
48	Psme/Phma-Phma	W	4220	1560-1893	12	15-52	30	104
50	Psme/Phma-Phma	SE	4120	1763-1908	6	15-62	29	89
			Range:	**1560-1920**	**3-14**	**5-77**	**23-38**	**77-137**
			Mean:	**-**	**8**	**10-62**	**30**	**107**

Fig. 7. Stand Fire Intervals

Mixed Severity I Regime (PP-WL-DF)

(N=13 stds)

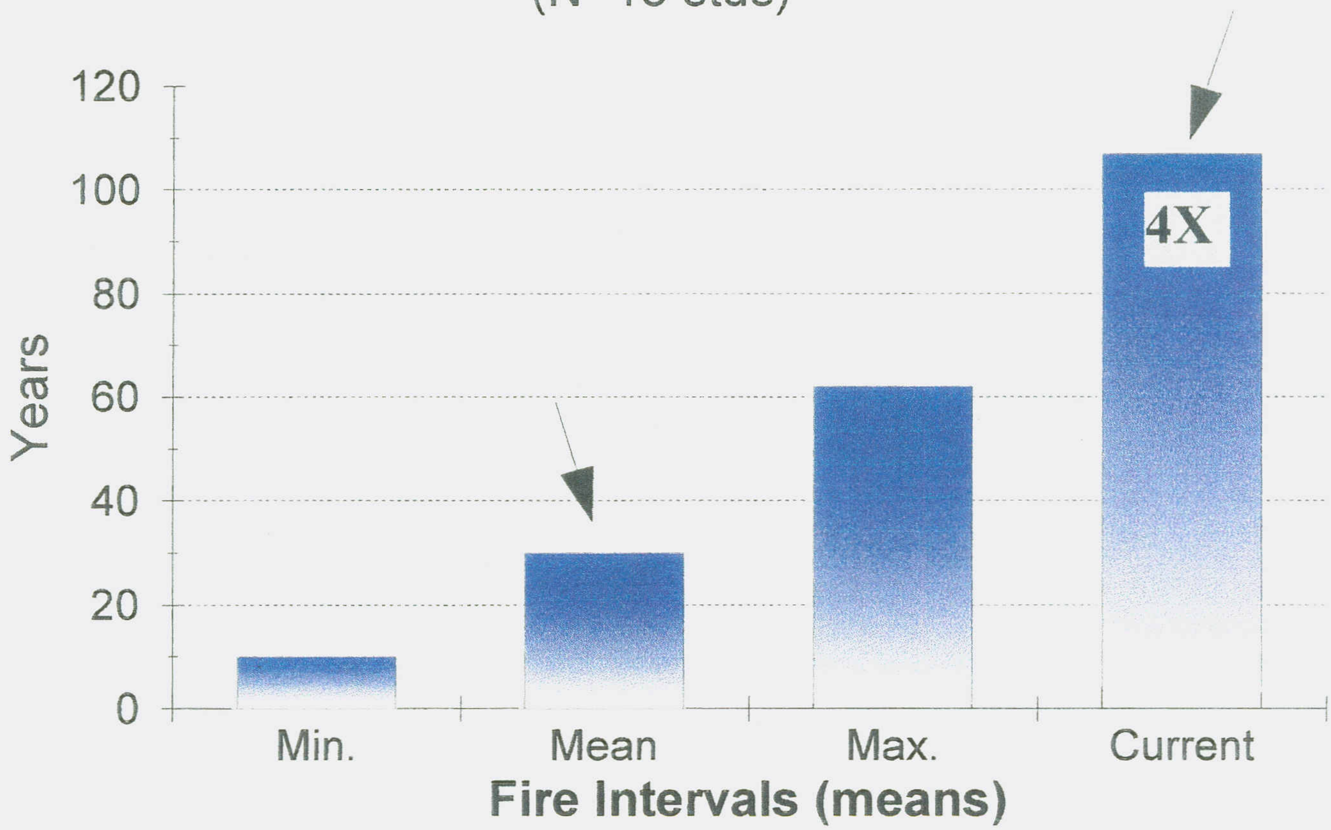


Fig. 8. MFI vs Years Since Last Fire, Mixed Severity I Regime

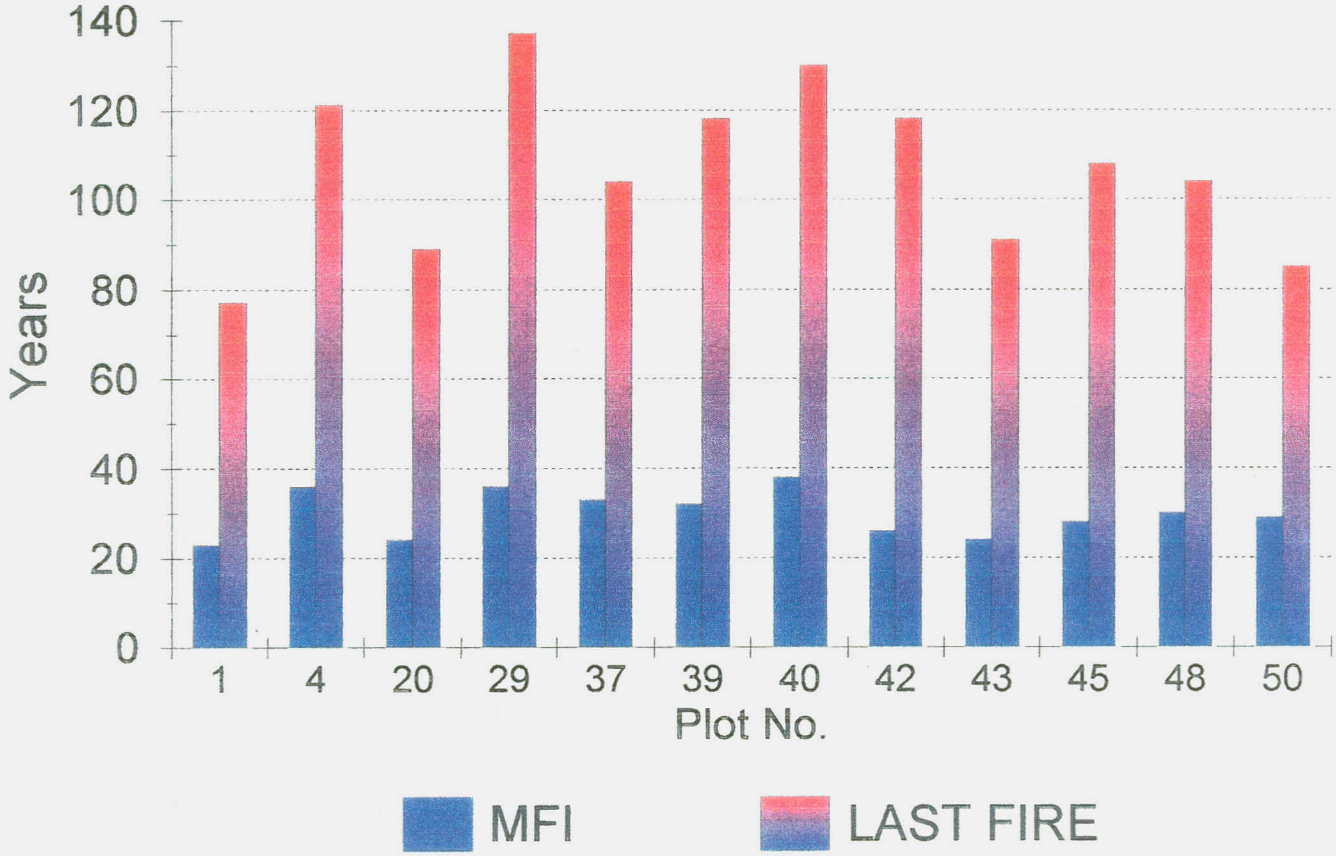


Table 3. Fire frequency- and stand data for 19 sample stands in the larch-lodgepole pine-Douglas-fir cover type (*Mixed Severity II Fire Regime*).

Plot No.	Habitat Type	Asp.	Elev. (ft)	MFC	No. Fires	Intvl. Range (yr)	MFI (yr)	Last Fire (yr)
3	Abgr/Clun-Clun	W	4450	1763-1920	7	12-51	26	77
7	Thpl/Clun-Clun	E	3640	1805-1893	2	(88)	-	104
8	Thpl/Clun-Clun	E	3800	1652-1908	3	103-153	128	89
11	Thpl/Clun-Clun	E	4000	1652-1908	4	15-155	85	89
15	Abla/Clun-Clun	NW	4600	1662-1908	3	94-152	123	89
16	Abgr/Clun-Clun	N	3800	1652-1920	8	12-111	38	77
18	Abgr/Clun-Xete	NW	4270	1686-1920	4	12-115	78	77
19	Abgr/Clun-Xete	NE	4200	1807-1920	2	(113)	-	77
22	Abla/Clun-Xete	S	5040	1686-1920	3	115-119	117	77
23	Abla/Xete-Vagl	N	5180	1686-1920	5	27-79	59	77
24	Abla/Xete-Vagl	SE	5080	1814-1920	2	(106)	-	77
26	Abla/Clun-Xete	W	4860	1686-1920	6	12-106	47	77
30	Abgr/Clun-Xete	W	4960	1681-1893	5	11-113	53	104
31	Abla/Clun-Xete	SW	5400	1540-1906	5	20-110	92	91
33	Abla/Clun-Xete	W	5300	1719-1893	4	30-77	58	104
34	Abgr/Clun-Xete	S	5120	1696-1906	5	13-119	53	91
36	Abla/Xete-Vagl	NW	5290	1662-1893	3	88-143	116	104
41	Abla/Clun-Xete	SW	5400	1814-1883	2	(69)	-	114
44	Abla/Xete-Vagl	W	5640	1847-1873	2	(26)	-	124
			Range:	**1540-1920**	**2-8**	**12-155**	**26-128**	**77-124**
			Mean:	**-**	**4**	**51-106**	**78**	**90**

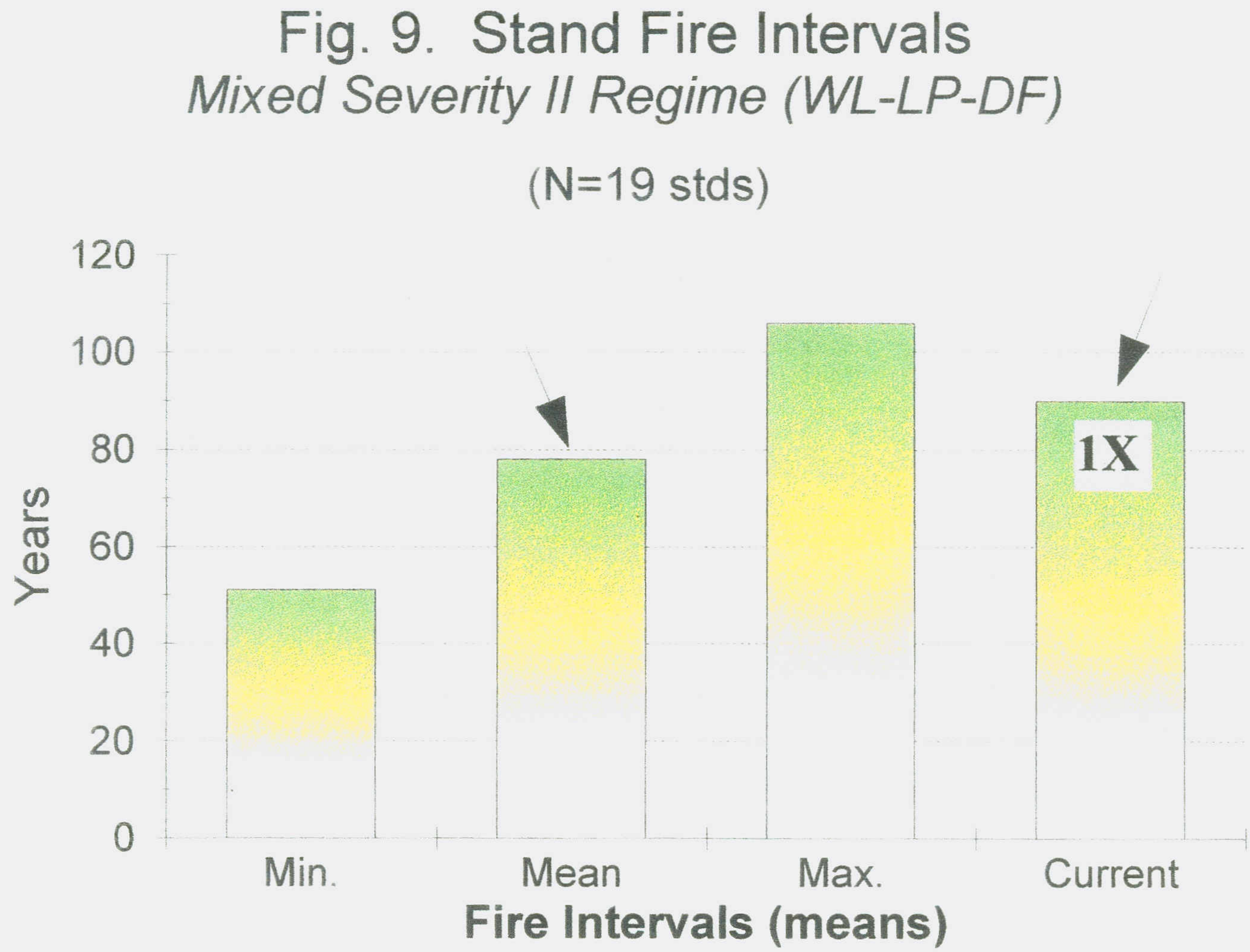
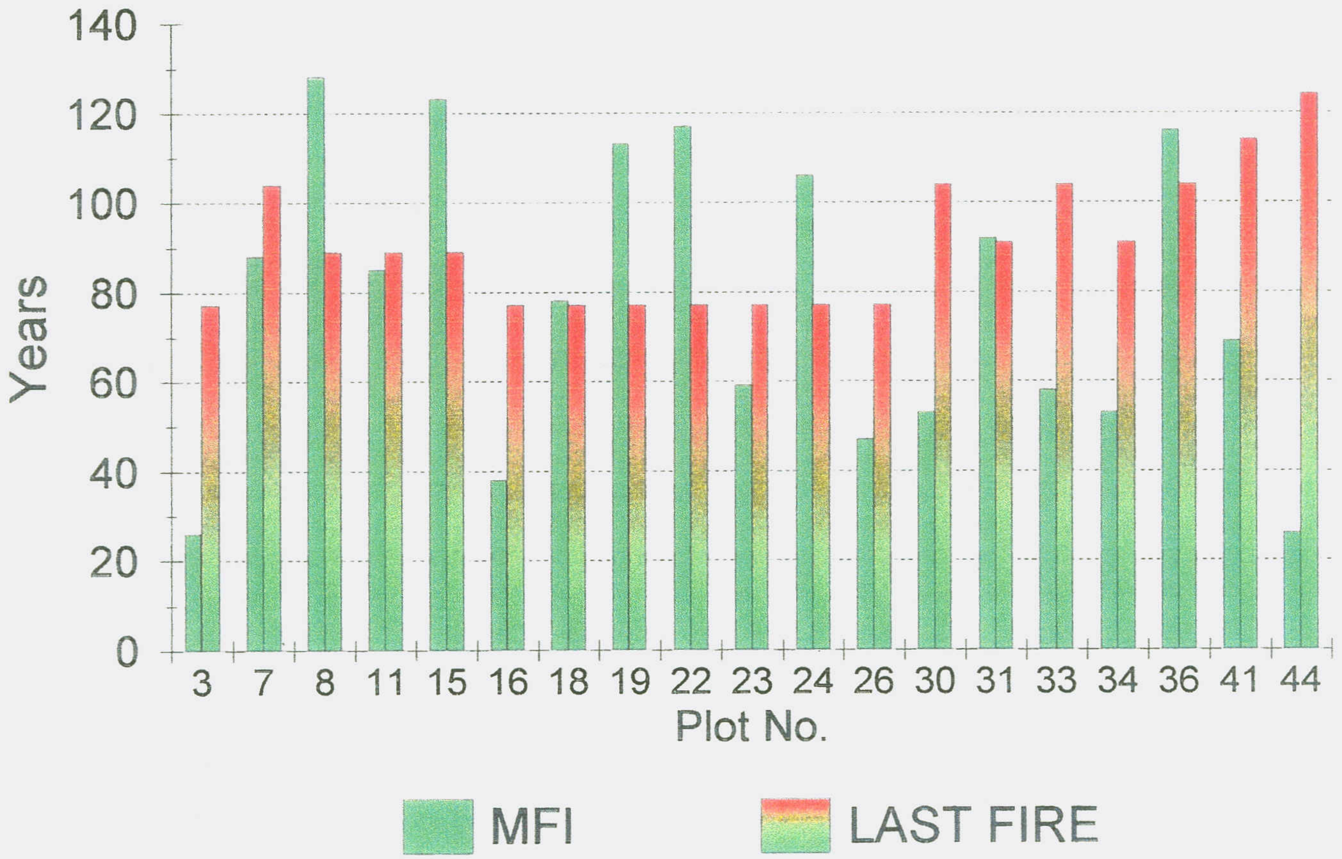


Fig. 9. Stand Fire Intervals
Mixed Severity II Regime (WL-LP-DF)
(N=19 stds)
120
100
80
60
40
20
0
Years
1X
Min.
Mean
Max.
Current
Fire Intervals (means)

Fig. 10. MFI vs Yrs Since Last Fire, Mixed Severity II Regime



underburns to partial- or total stand replacement on any given site. Consequently, such stands contain more species- and structural diversity than in ponderosa pine stands (Barrett et al. 1991 Arno et al. 1995, Arno et al. 1997, Elzinga and Shearer 1997).

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Fire Patterns at the Landscape Scale.

Presettlement Period. The forest age class mosaic, generated by 50 or more fires over the last five centuries, is highly complex in the study area. Succession during the eight-decade long fire exclusion period has also masked old burn margins. Rather than mapping stand origins (Heinselman 1973, Barrett et al. 1991), the fire history data were used to model the areal extent of the three fire regime types. Groups of ecologically similar habitat types (on file, FNF Geographic Information System [GIS]) were used to stratify the study area by forest cover type and associated fire regime type. All sparsely forested south slopes in the ponderosa pine-Douglas-fir type were assigned to the *high frequency/low severity* (Nonlethal) fire regime. The adjacent ponderosa pine-larch-Douglas-fir cover type was assigned to the *moderately high frequency/low to moderate severity* (Mixed Severity I) presettlement fire regime. Finally, the larch-lodgepole pine-Douglas-fir cover type was classified as the *moderately low frequency/moderate to high severity* (Mixed Severity II) fire regime.

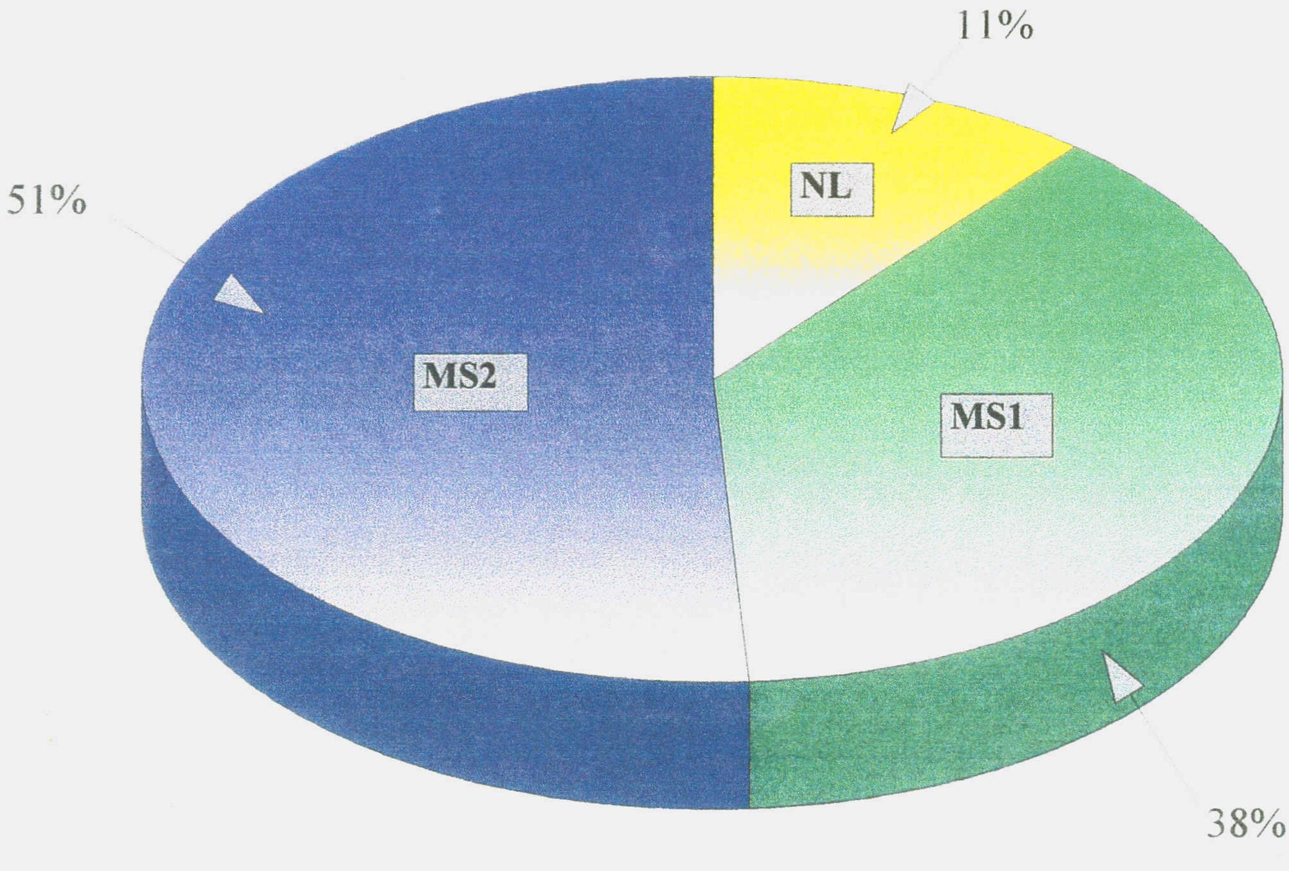
The model (figs. 11-12) suggests that 11 percent of the stands in the study area had a nonlethal fire regime during the presettlement era (i.e., *PP-DF* c.t.). Thirty-eight percent occur in the Mixed Severity I presettlement fire regime (i.e., *PP-WL-DF* c.t.). The remaining 51 percent of the stands occur in the Mixed Severity II presettlement fire regime (i.e., *WL-LP-DF* c.t.).

Fire Exclusion Period. After the fire regimes were modeled, a fire exclusion map was developed for the study area. The objective was to interpret the effectiveness of fire exclusion at the landscape scale, by determining an average "fire exclusion factor" for all stands. First, data from the fire atlas and sample stands were used with aerial photographs to map the approximate boundaries of the last fires in each drainage (fig. 13). Because fire margins are now obscure, most polygons were labeled by fire period rather than by fire year (e.g., "1908-1920"). These polygons were superimposed on the fire regimes map to determine an average fire exclusion factor for each area. For example, the current fire interval for Beardance is about 90 years (i.e., period midpoint). For the ponderosa pine-larch-Douglas-fir type, dividing the 90-year long current fire interval by the 30-year average MFI yields an average fire exclusion factor of three (i.e., a 200% increase in interval length). The fire exclusion factor equals one for the adjacent larch-lodgepole-Douglas-fir stands (i.e., 90/80 = 1x ["*No Change*"]). The results for Beardance thus suggest that the ponderosa pine fire cycle is seriously out of balance, whereas the larch-lodgepole-Douglas-fir fire cycle is still within the range of natural variability.

The GIS produced the following results (figs. 14-15). Thirty percent of all stands have current fire intervals that are roughly equal to the average MFI. These stands occur in the larch-lodgepole-Douglas-fir cover type, largely in the northeast sector. Stand fire cycles in the remaining 70 percent of the study area appear to be substantially out of balance. Specifically, the fire exclusion map suggests that 39 percent of all stands have current fire intervals ranging from 100 to 200 longer than the average MFI. Moreover, the remaining 31 percent have current fire intervals ranging from 300 to 500 percent longer than the average MFI.

The fire exclusion model yielded the following results for each fire regime type (fig.16). The

Fig. 11. Area Fire Regimes
Flathead Lake East Shore Analysis Area



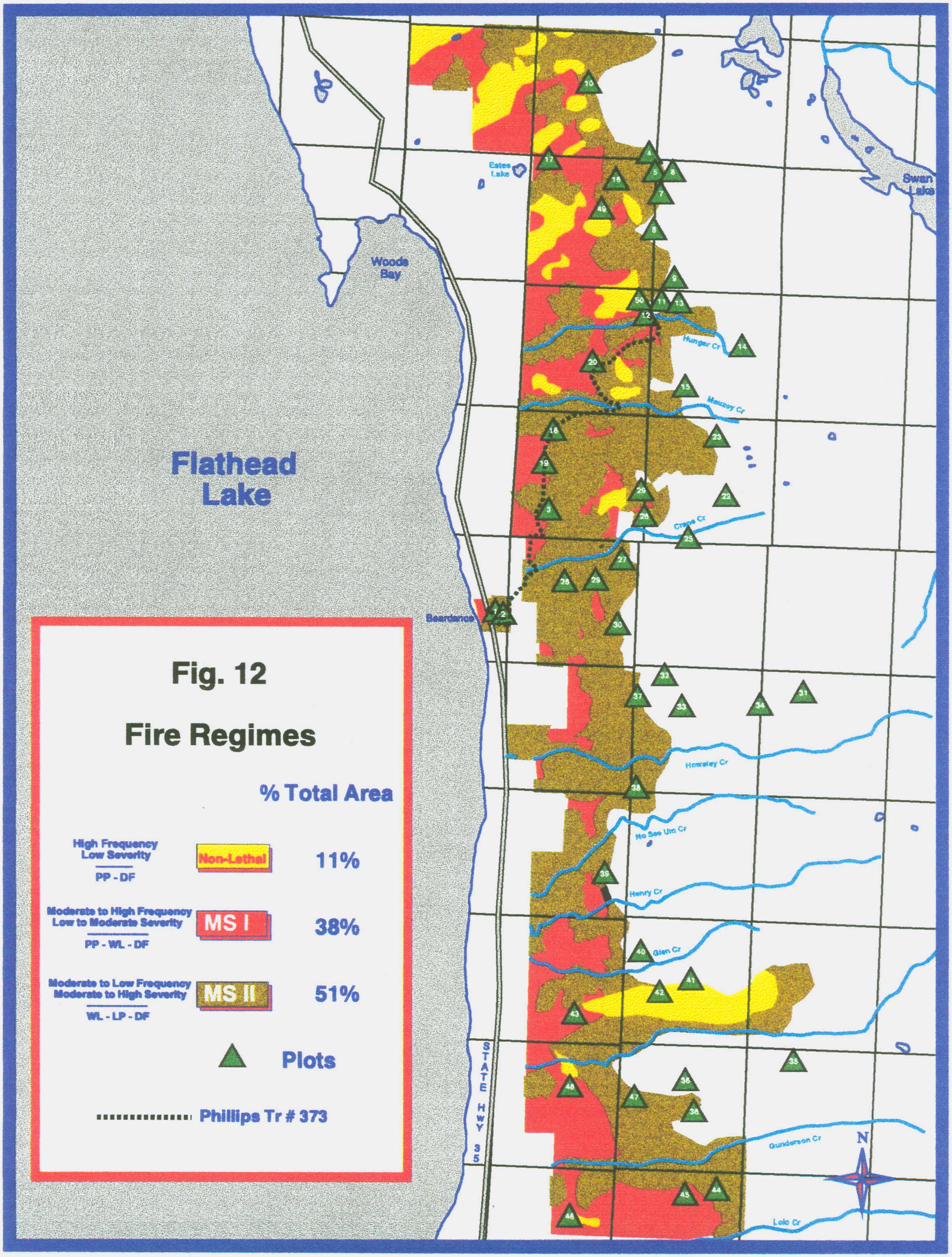


Fig. 12

Fire Regimes

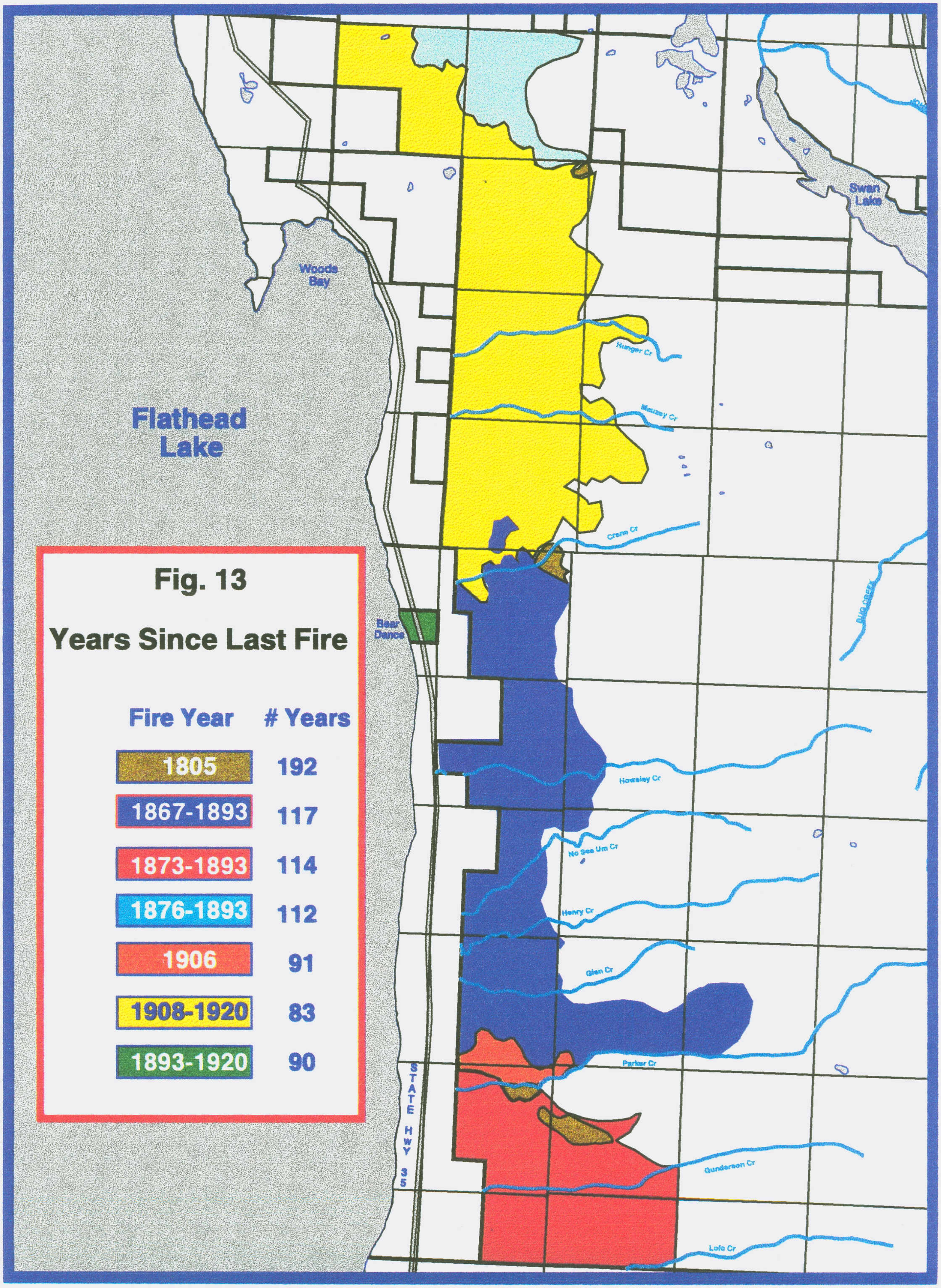


Fig. 13

Years Since Last Fire

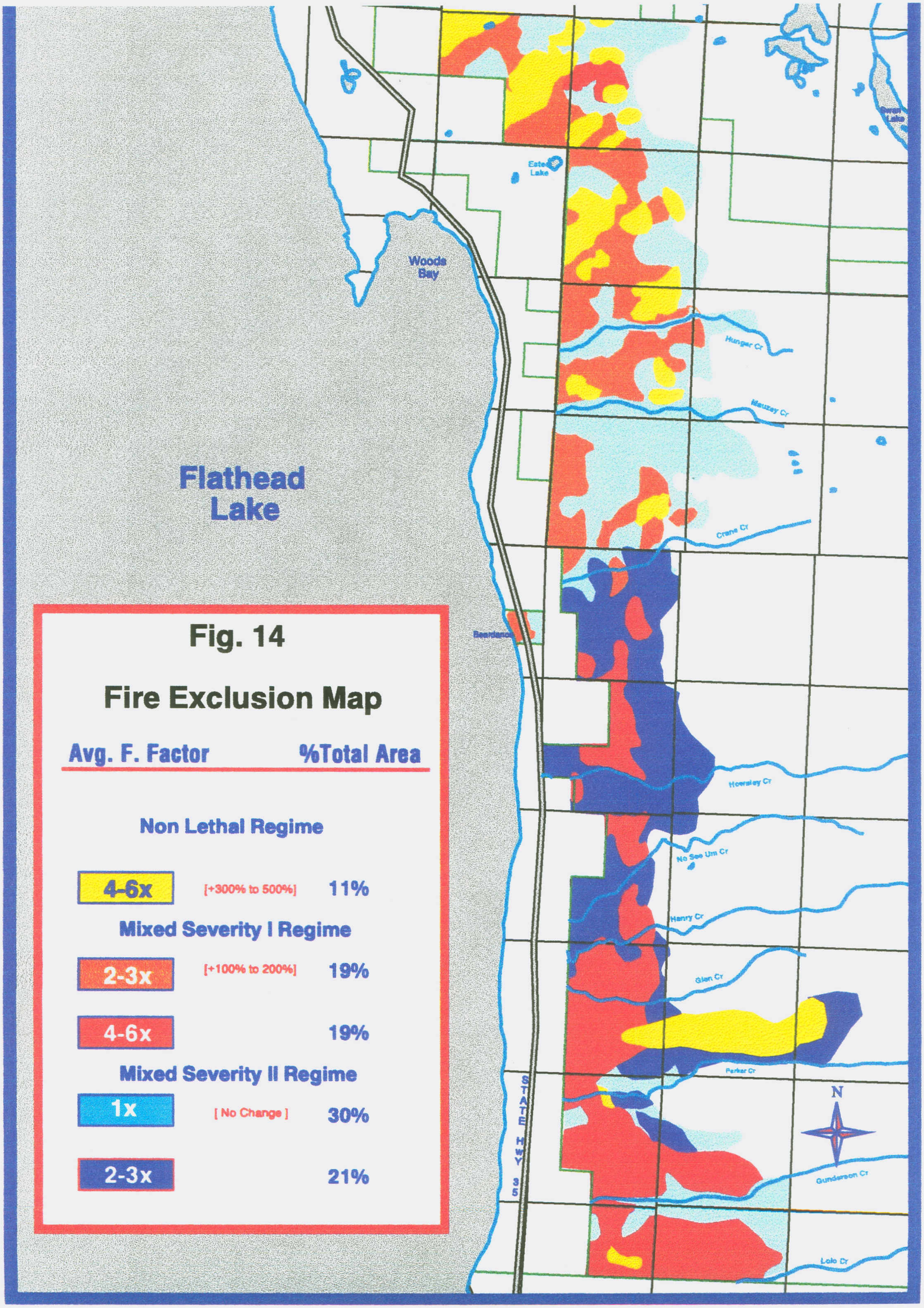
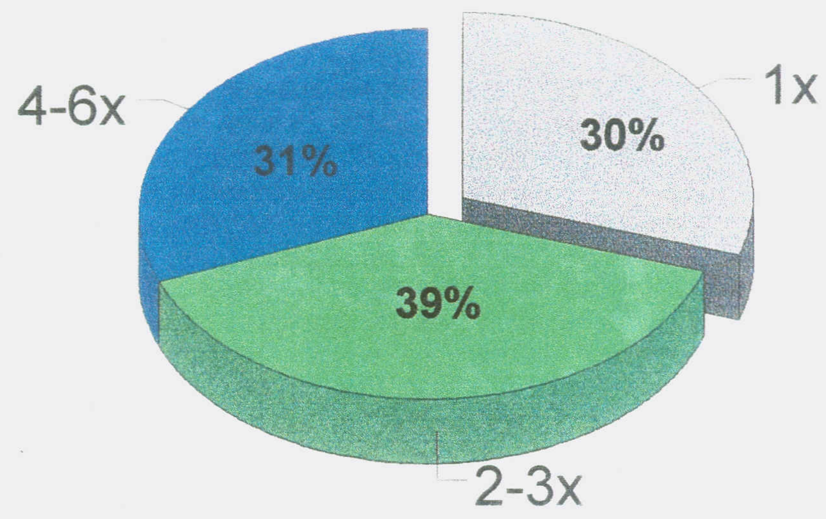


Fig. 14
Fire Exclusion Map
Avg. F. Factor
%Total Area
Non Lethal Regime
4-6x
[+300% to 500%]
11%
Mixed Severity I Regime
2-3x
[+100% to 200%]
19%
4-6x
19%
Mixed Severity II Regime
1x
[No Change]
30%
2-3x
21%
Flathead Lake
Woods Bay
Hunger Cr
Crane Cr
Henry Cr
Glen Cr
Parker Cr
Gunderson Cr
Lolo Cr
STATE HWY 35
N

Fig. 15. Avg. Fire Exclusion Factor
By Percent of Study Area



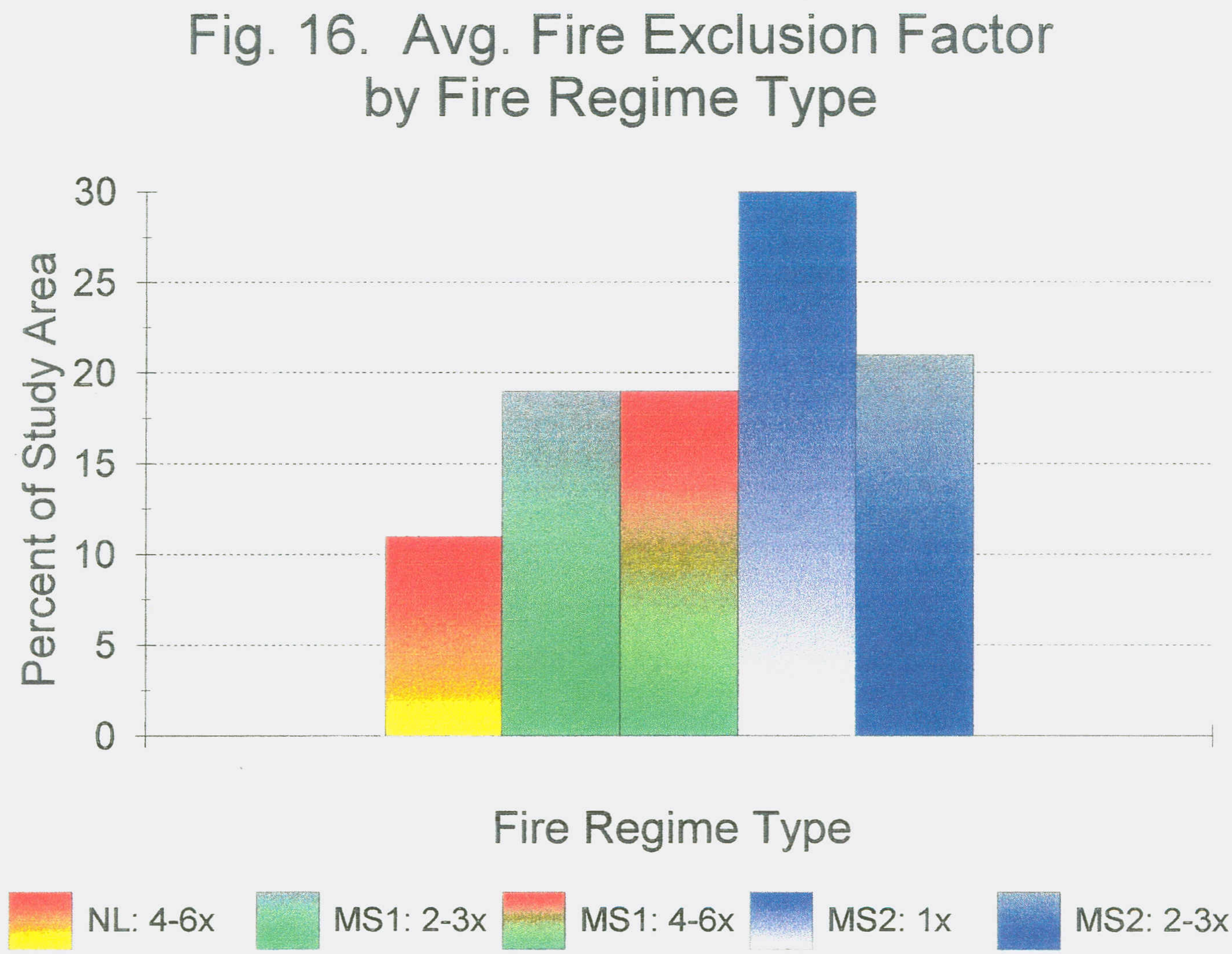


Fig. 16. Avg. Fire Exclusion Factor
by Fire Regime Type
Percent of Study Area
30
25
20
15
10
5
0
Fire Regime Type
NL: 4-6x
MS1: 2-3x
MS1: 4-6x
MS2: 1x
MS2: 2-3x

map suggests that all stands in the nonlethal fire regime (*PP-DF* c.t.) have current fire intervals ranging from 300 to 500 percent longer than the average MFI of 20 years. All stands in the Mixed Severity I fire regime (*PP-WL-DF* c.t.) have current fire intervals ranging from 200 to 300 percent longer than the 30-year average MFI. Together, these ponderosa pine-dominated stands occupy half the study area. The remaining half occurs in the Mixed Severity II regime (*WL-LP-DF* c.t.), which shows varying influence from fire exclusion. Current fire intervals in about two-thirds of the stands, totalling about 30 percent of the study area, are similar in length to the 80-year long average MFI. However, the fact that these fire intervals are still within the range of natural variability does not mean that the stands have been unaffected by fire exclusion. Without long-term fire exclusion, some stands undoubtedly would be in early post-fire succession, rather than at mid-succession. Current fire intervals in the remaining larch-dominated stands, about 21 percent of the total study area, range from 100 to 200 percent longer than the average MFI.

The northern half of the study area (i.e., north of Beardance) has been somewhat less affected by fire exclusion. Because much of that area burned in the early 1900s (fig. 14), most of the larch-dominated stands are now at mid-succession. In the northwestern half, however, most ponderosa pine stands are now experiencing late post-fire succession. Specifically, the fire exclusion map suggests current fire intervals in these stands range from 100 to 500 percent longer than the average MFI. In the southern half of the study area, most current intervals are long irrespective of fire regime type. The ponderosa pine stands south of Henry Creek, for example, have some of the longest current fire intervals of any stands in the study area.

Successional Trends. Plots at the 50 sample sites were used to document pre- and post-1900 successional trends. These data suggest that fire exclusion has markedly disrupted stand structure and species composition in most ponderosa pine-dominated stands, particularly on the relatively moist sites. Frequently burned stands were dominated by widely spaced, fire-resistant serals (i.e., old ponderosa pines and larches)(figs. 17-19). However, long-term fire exclusion has promoted canopy closure and increasingly heavy dominance by shade tolerant species in most ponderosa pine stands. Many are now highly decadent because of overstocking, mistletoe infections, and bark beetle attacks. Root rot pockets and heavy downfalls are also common. (A recent field inspection by Forest Service R-1 specialists verified that mistletoe and root rots have reached epidemic proportions in the Beardance area). Downed fuels combined with thickets of understory ladder fuels have also promoted a shift in fire potential, from mixed severity- to stand replacement fires (Agee 1993).

Most ponderosa pines on Crane Mountain evidently regenerated after fires during warm-dry climatic periods (Karl and Koscielny 1982, Graumlich 1987, Meko et al. 1993, Barrett et al. 1997) between circa 1500 and 1750. Conversely, larch and lodgepole pine age classes often became established after relatively severe fires in the early- to mid-1800s, during the height of the cool-moist Little Ice Age. Despite a subsequent return to a warm-dry climate, few ponderosa pines have regenerated during the last 100 years. The only noteworthy regeneration occurred near lower Gunderson Creek after the 1893 fire, followed by total fire exclusion. Some members of that age class succumbed during a recent pine beetle epidemic — due in part to a lack of thinning fires after initial establishment.

Data from previous studies (Lunan and Habeck 1973, Freedman and Habeck 1985, Arno et

Fig. 17. Successional Trends,
All Stands, PP-WL-DF Cover Type

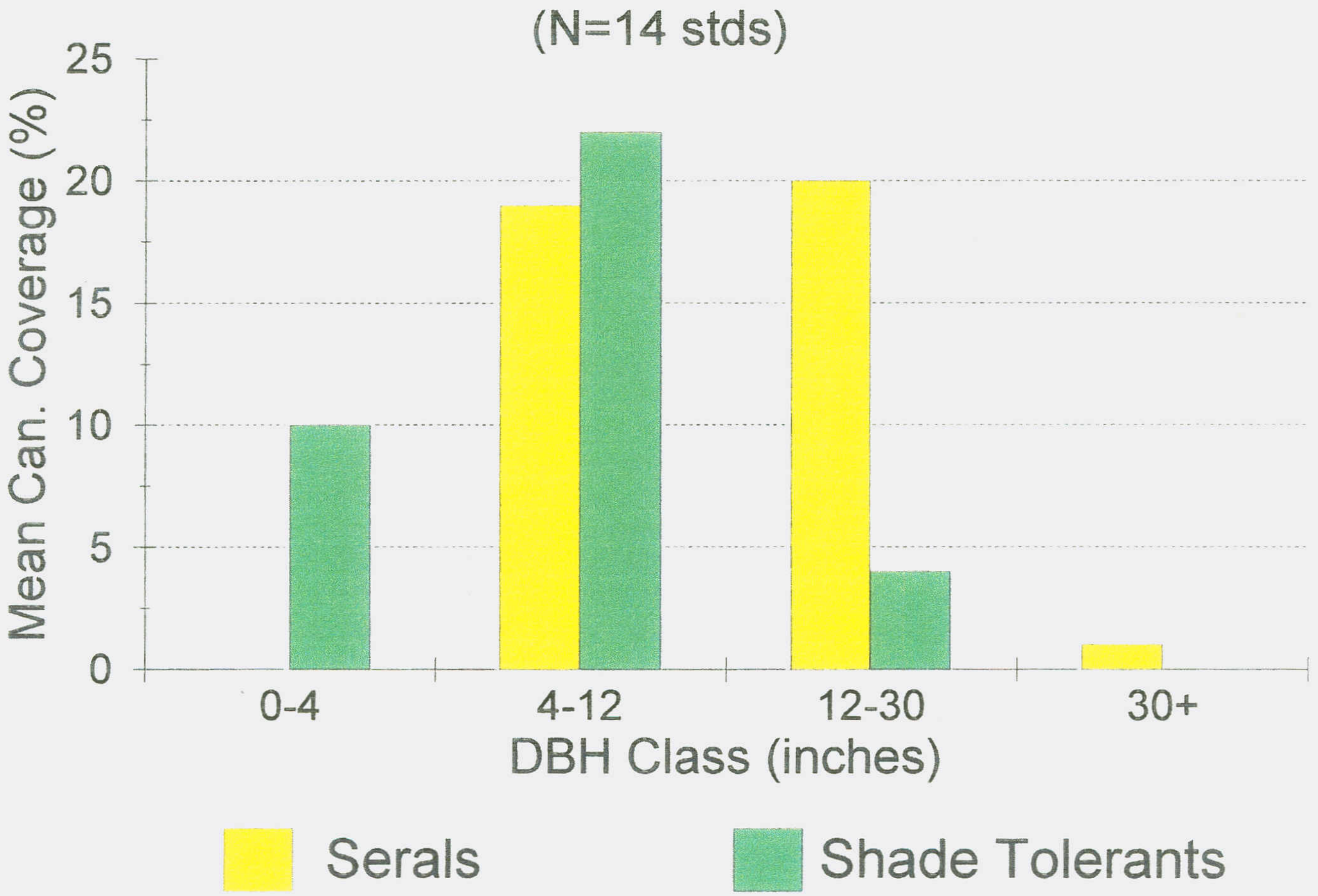


Fig. 18. Successional Trends,
PP-WL-DF Stands with F. Factor 2-3x

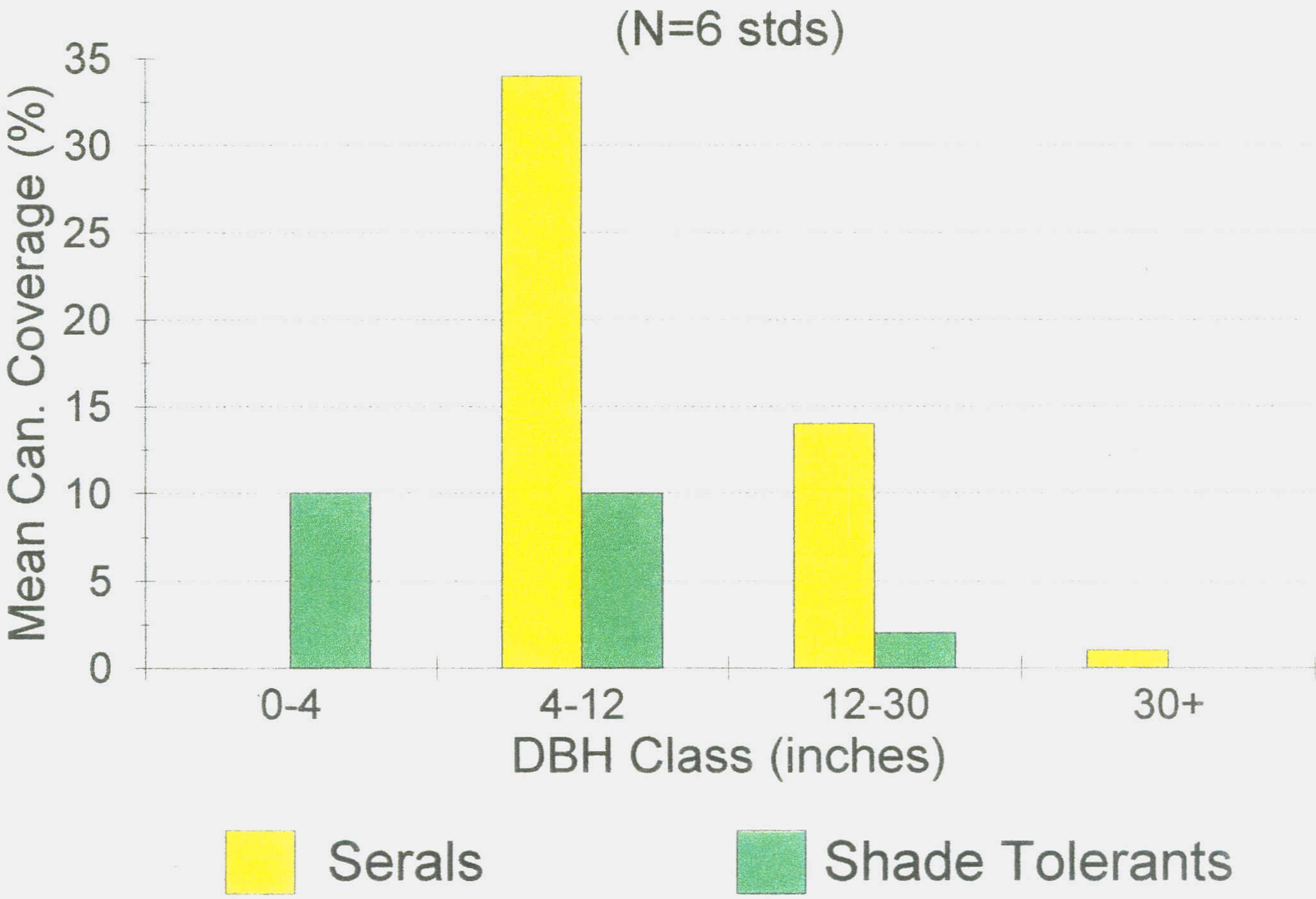
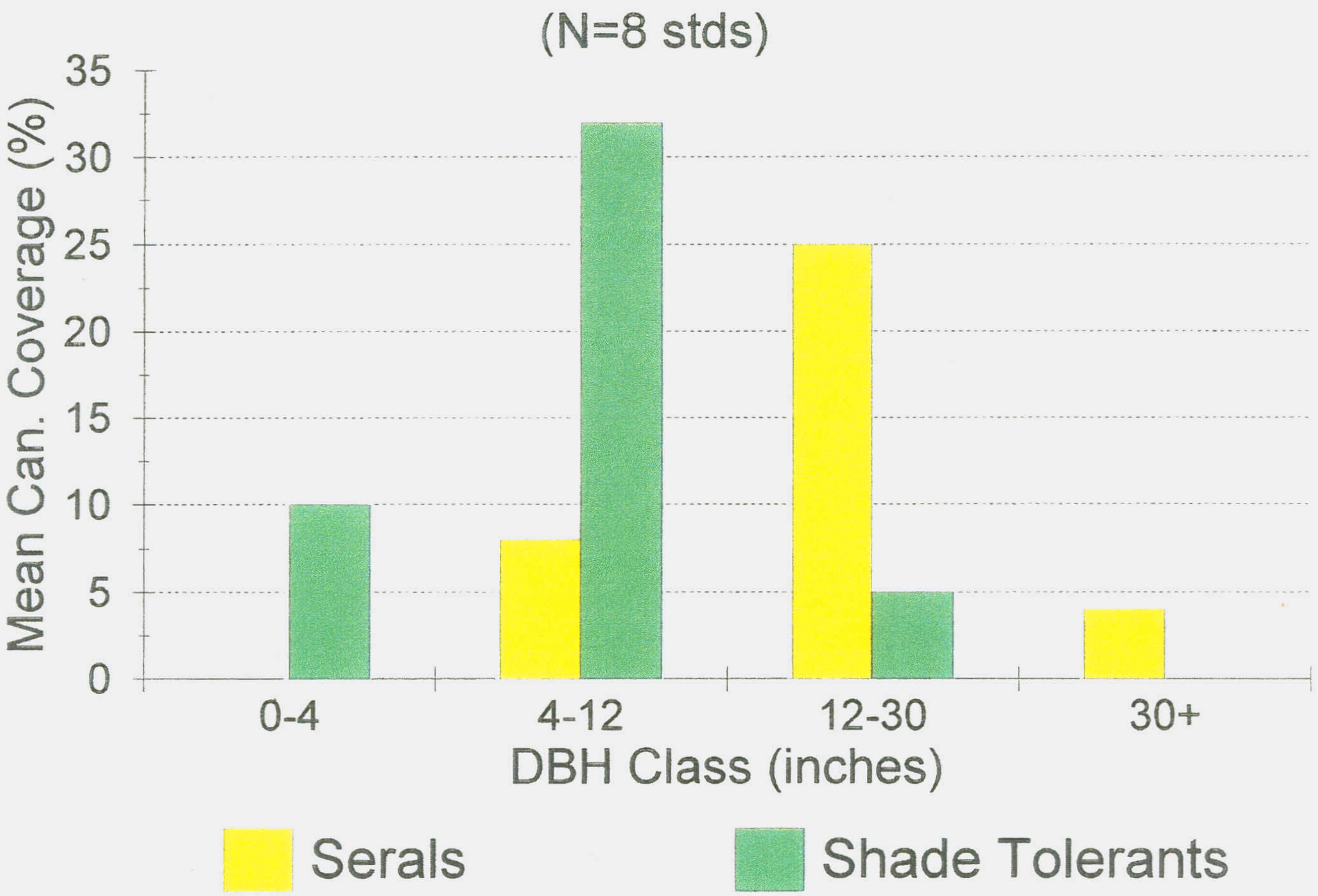


Fig. 19. Successional Trends,
PP-WL-DF Stands with F. Factor 4-6x



al. 1995) on similar habitat types support these findings. In the Swan Valley, for example, stand MFIs ranged from 20 to 30 years, but fires had largely ceased by the mid- to late 1800s (Freedman and Habeck 1985, Arno et al. 1995). The stands were dominated by just 50 or 60 mature ponderosa pines per acre before 1900, but infilled markedly during the fire exclusion period. By the 1990s, stand basal area had increased by from 50 to 150 percent, with shade tolerant trees comprising most of the post-1900 regeneration (Arno et al. 1995).

The effects of fire exclusion are often less apparent on dry southerly aspects (e.g., in the 900 series of habitat types)(figs. 20-22). Although these stands have some of the longest current fire intervals, many sites remain lightly stocked because of thin soils and inherently high drought stress (Pfister et al. 1977). Still, scattered thickets of Douglas-fir are producing high fuel concentrations locally. Long-term accretion of litter and duff can also promote lethal scorching of tree root crowns during fires, and surviving scorched trees often become vulnerable to insects and diseases (Barrett 1988, Arno et al. 1995). Additionally, fire exclusion has allowed trees to invade some previously unforested sites, reducing the size and vigor of those communities (Lunan and Habeck 1973, Barrett et al. 1991). Without repeated fires, shrub vigor and nutrient content has diminished (Freedman and Habeck 1985), and many shrubs have grown beyond the reach of browsing animals.

The effects of fire exclusion have been more variable in the larch-lodgepole pine-Douglas-fir cover type. While most stands are still experiencing natural succession (figs. 23-25), the fire exclusion map suggests that 40 percent of the stands have current fire intervals that are two to three times longer than the average MFI. Fire exclusion alone did not produce this result, but may have lengthened some fire intervals that began in the early 1800s. Regardless of current fire intervals, most larch-dominated stands contain substantial fuel loads well able to burn — next to a ponderosa pine forest heavily impacted by fire exclusion. Consequently, the study area now might be vulnerable to wildfires of unprecedented size and severity, when compared with the presettlement patterns. This scenario is probable because aggressive fire suppression undoubtedly can eliminate all but the most dangerous fires on Crane Mountain (i.e., fires escaping during worse than "average bad" conditions). Unnaturally severe fires have already occurred in similar forest types elsewhere in the Flathead Basin. In 1988, for example, the uncontrollable Red Bench Fire near Polebridge destroyed most stands within a 38,000 acre perimeter (Barrett et al. 1991).

Implications for Management. Fire history research can be a useful planning tool for ecologically-based forest management (Arno and Brown 1989, Mutch et al. 1993, Mutch 1994). In planning for forest restoration, managers can use fire regimes information to identify and prioritize areas that could benefit from prescribed fire and fuels management silviculture. Specifically, data from sample stands and the fire exclusion model show which stands have been heavily affected by fire exclusion, versus areas still experiencing natural succession.

Fire history data can be used to design management activities that simulate past fire disturbance. For example, thinning harvests would be appropriate restoration treatment for all fire regime types in the analysis area, and prescriptions could vary by forest type. Uneven-age systems, or prescribed fires, would be appropriate for dry stands in the 900 series of habitat types. Prescriptions could incorporate

Fig. 20. Successional Trends,
All Stands, PP/DF Cover Type

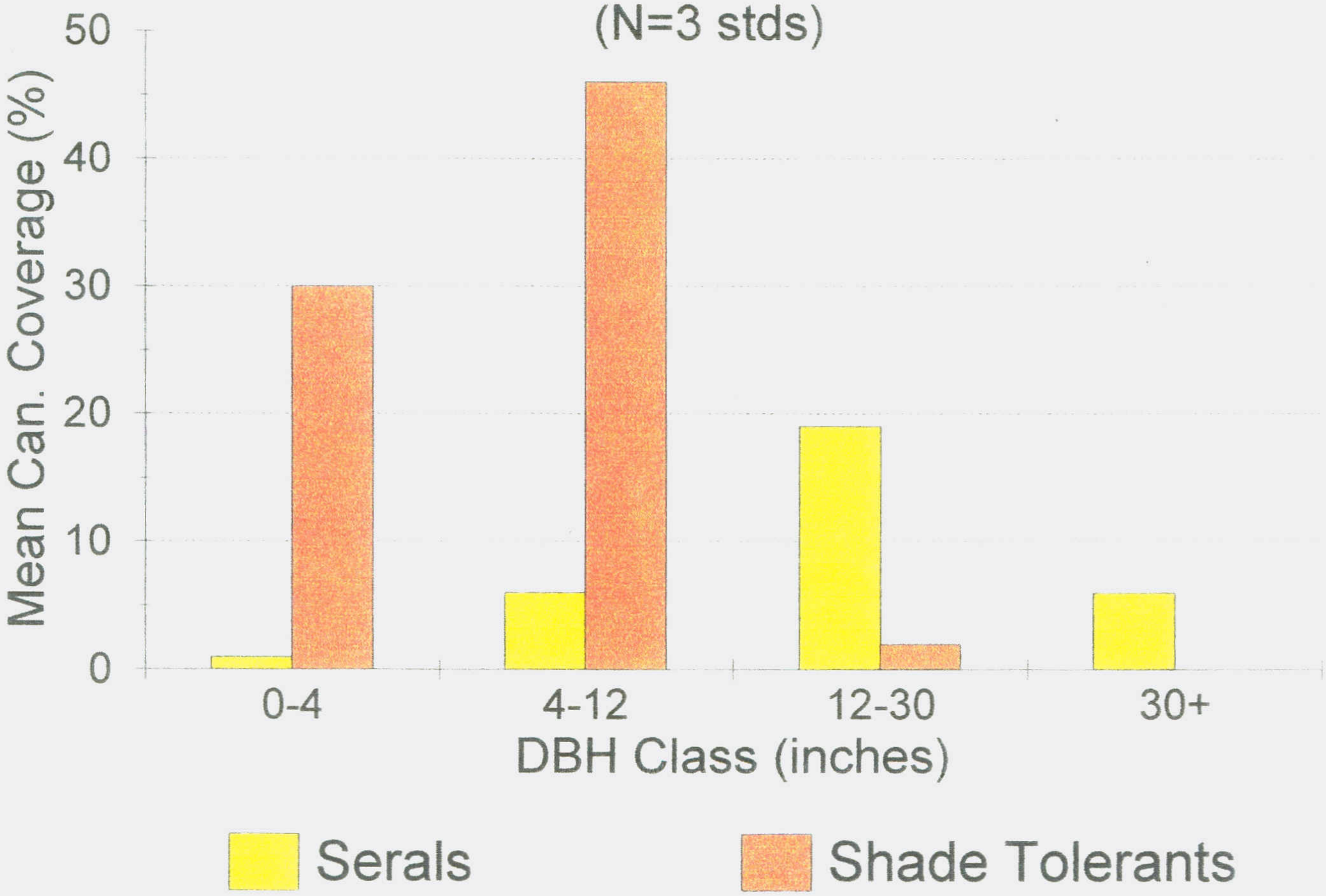


Fig. 21. Successional Trends,
PP/DF Stands with F. Factor 2-3x

(N=1 std)

Fig. 22. Successional Trends,
PP/DF Stands with F. Factor 4-6x
(N=2 stds)

Fig. 23. Successional Trends, MS2
All Stands, WL-LP-DF Cover Type

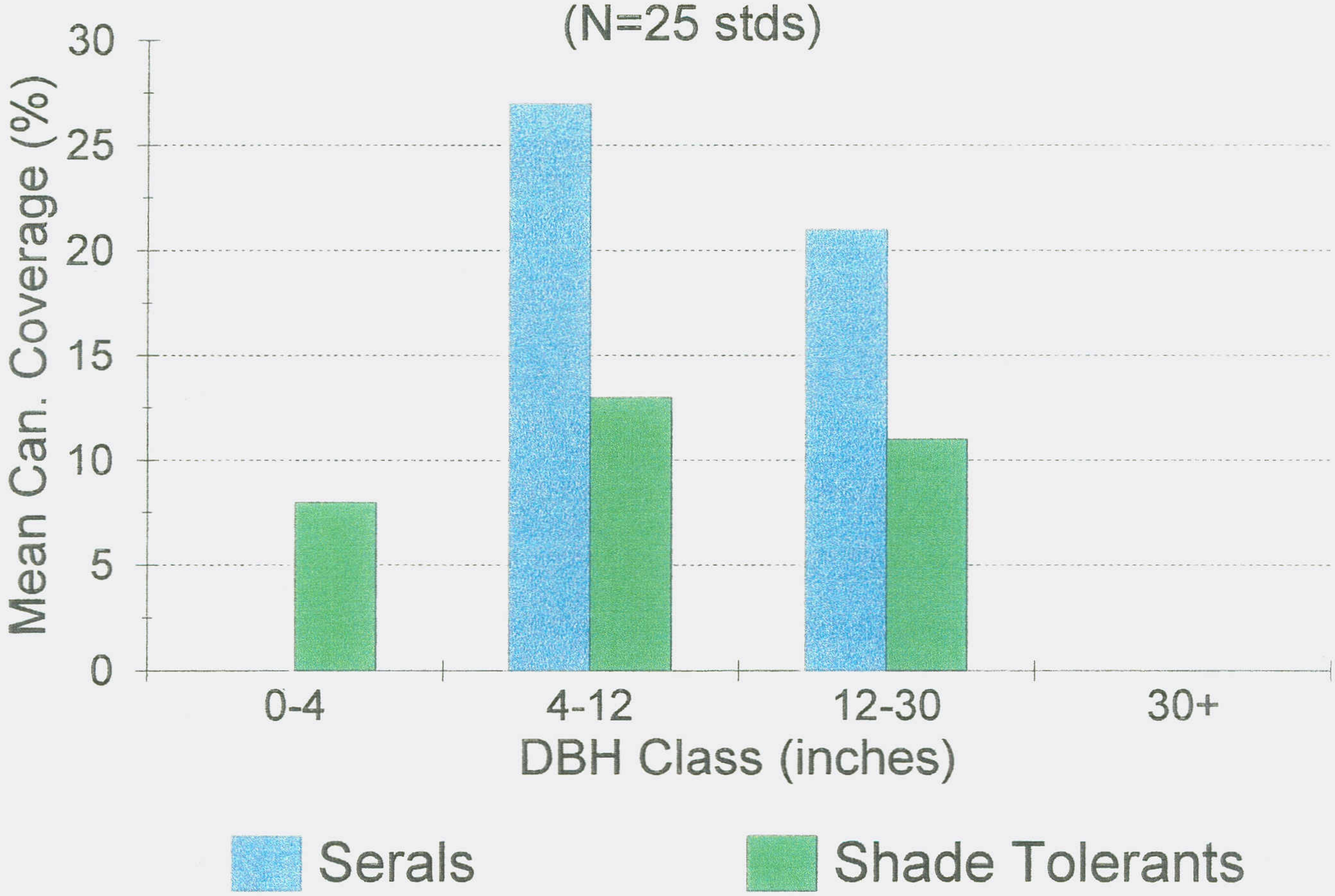


Fig. 24. Successional Trends, MS2

WL/LP/DF Stands with F. Factor 1x

(N=20 stds)

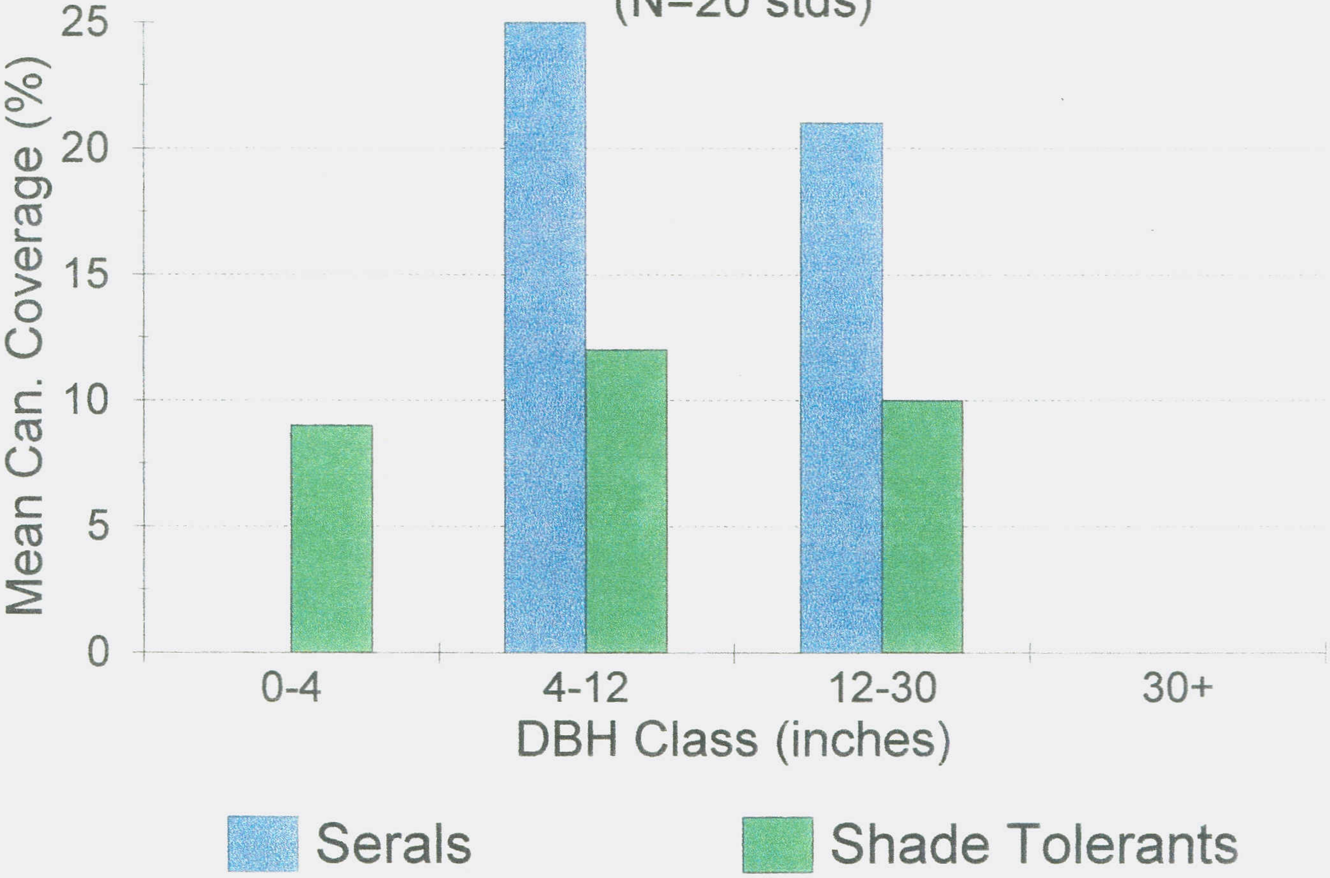
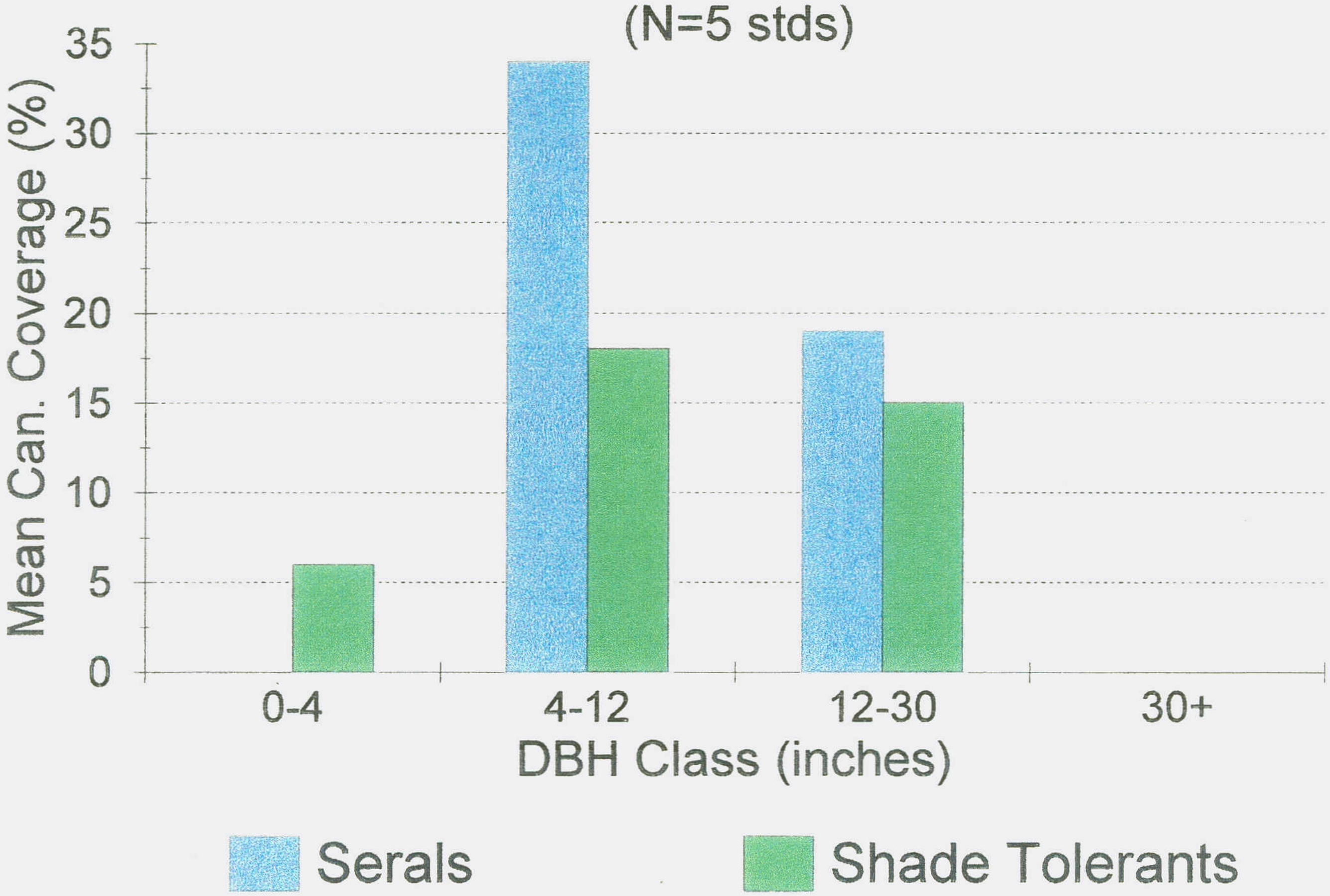


Fig. 25. Successional Trends, MS2

WL/LP/DF Stands with F. Factor 2-3x



an initial light- to moderate thinning of understory poles, followed by individual-tree selection during future entries (Arno et al. 1995). Post-restoration entries could be scheduled to replicate the past range of fire intervals (e.g., 10-50 yr). Conversely, prescribed fire alone might be sufficient for restoring natural succession on unforested sites in the 900 series.

For moist ponderosa pine stands, an initial moderate- to heavy thinning of understory poles would help restore historical stand structures. To simulate low- to moderate severity fires, subsequent harvests could use various combinations of uneven and even age systems, depending on site type and stand variability. For instance, individual-tree selection might be appropriate on sites dominated by old, widely spaced ponderosa pines. Conversely, individual tree- and small group selection would replicate the effects of mixed severity fires on sites co-dominated by ponderosa pine and western larch (Arno et al. 1997). Long-term prescriptions could schedule re-entries to simulate past fire intervals (e.g., 10-80 yr), and small- to moderate-size units (e.g., 20-100 acres) would replicate past fire sizes. However, a comparatively large buffer zone might be necessary for fuel hazard reduction near the urban interface.

For the larch-lodgepole pine-Douglas-fir type, various prescriptions would maintain stand structures similar to those produced by widely ranging fire severities and frequencies. For example, moderate to heavy thinning of understory poles in multi-age stands would help perpetuate old larches, while recruiting new seral age classes. In lodgepole pine-dominated stands, group selections would imitate the relatively severe fires that recycled that species. To simulate the scale of past disturbances, treatments might range from 20 acres to 1000 acres in size. In terms of re-entries, intervals ranging from 50 to 150 years would simulate those produced by fires. (Also note that detailed structural- and compositional data for both ponderosa pine- and larch-dominated old growth stands appear in Arno et al. [1995 and 1997]).

For landscape-scale planning, area fire cycles (Romme 1980) can help guide in scheduling and monitoring cumulative disturbance over time. For example, fire cycles can be calculated for each fire regime type by dividing the total acreage by the representative stand MFI. In the nonlethal fire regime, fires burned an average of 35 acres per year (5%) of the 690 total acres occupied by that type (i.e., 690 ac. divided by 20 avg. MFI). Fires burned an average of 76 acres per year (3%) of the 2290 acres occupied by the ponderosa pine-larch-Douglas-fir cover type in the Mixed Severity I regime. Presettlement fires burned an average of 38 acres per year (1%) of the larch-lodgepole pine-Douglas-fir cover type in the Mixed Severity II regime. In sum, fires burned an average of about 150 acres per year in the study area, or, acreage equal to the total study area every 40 years. (Although virtually no acres have burned since 1920, the study area theoretically would have burned *twice* during the past eight decades). Accordingly, managers can use such information to monitor the level of disturbance from both natural and cultural sources, such as fires or fuels management silviculture.

SUMMARY

From at least 1500 to 1920, mixed severity- and nonlethal fires were frequent in the Crane Mountain area. However, fire cycles have been substantially disrupted by long-term fire exclusion, producing fundamental changes in area ecosystems. At the stand scale, *species composition* has shifted in most ponderosa pine-dominated stands. Whereas pre-1900 stands were dominated by early seral species, shade tolerant species now dominate on fire-excluded sites. *Stand structures* have also changed. Tree densities in ponderosa pine stands have shifted from light- to heavy stocking, greatly increasing the level of tree competition and promoting stand decadence. At the landscape scale, the study area is experiencing *artificially induced mosaic homogeneity* (Romme 1982, Romme and Knight 1982, Barrett et al. 1991, Brown et al. 1994). That is, repeatedly extinguishing fires over the past eight decades has reduced forest age class diversity and, hence, landscape biodiversity. Besides posing a threat to some of the last old growth ponderosa pines in the main Flathead Valley, fire exclusion has thus reduced overall ecosystem integrity. And finally, *area fire hazard* is increasing, threatening the nearby urban interface.

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APPENDIX

Master Fire Chronology (*Year: No. Plots*).

20th Century	19th Century	18th Century	17th Century	16th Century
1920: 9	1893: 22	1798: 3	1696: 4	1580: 3
1908: 11	1889: 1	1794: 4	1686: 6	1560: 2
1906: 3	1887: 1	1786: 2	1681: 3	1535: 2
	1883: 1	1782: 3	1678: 1	1513: 3
	1879: 3	1770: 7	1662: 6	
	1876: 3	1763: 6	1652: 6	
	1873: 7	1757: 4	1644: 3	
	1867: 4	1744: 5	1632: 1	
	1860: 8	1735: 5	1627: 1	
	1856: 2	1729: 3	1612: 2	
	1852: 3	1723: 1		
	1847: 2	1719: 4		
	1840: 1	1714: 7		
	1839: 1	1707: 6		
	1827: 1			
	1820: 3			
	1814: 14			
	1805: 24			

Master Fire Chronology: 1513-1920
Number of Fires: 49
Fire Interval Range: 1-32 yr.
Mean Fire Interval: 9 yr.
Years Since Last Fire: 77 yr.